BigSkyEarth Conference: Education in Big Data Era

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TITLE: EARTH OBSERVATION PARADIGM SHIFT: BIG DATA ANALYTICS

Keywords: Earth Observation, Big Data

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The Earth is facing unprecedented climatic, geomorphologic, environmental and anthropogenic changes, which require global scale observation and monitoring. Thus resulting in a multitude of new orbital and suborbital Earth Observation (EO) sensors. Particularly the Very High Resolution Satellite images, are providing a wealth of information, spatial, multi-temporal, physical parameters. However, due to their inherent complexity and also very large volumes, their automatic analysis and information extraction needs to be further evolved. Since their instrument nature, image processing or computer vision methods are not always suitable, new methods need to be developed. The presentation aims to enlarge the preoccupation of the image processing/computer vision towards the particular challenges of VHR EO information extraction, particularly to image understanding and information mining.

ASSIMILATION OF ATMOSPHERIC WATER VAPOR MEASUREMENTS: HOW DATA SCIENCE CAN CONTRIBUTE TO THE VISUALIZATION AND SURFING OF INFORMATION CONTENT

Keywords: Atmosphere, Numerical Weather Models (NWM), SAR interferometry, GNSS

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Recently new applications of traditional Earth Observation (EO) techniques, e.g. GNSS and Synthetic Aperture Radar (SAR) Interferometry, have proven the capability to sense the atmospheric water vapor and provide high resolution maps of the Precipitable Water Vapor (PWV) and 3D reconstructions of refractivity related to the atmospheric water vapor. This information is provided by many spaceborne missions (e.g. ESA Sentinel-1 A&B, CSA Radarsat-2 in C-band, JAXA ALOS-2 in the L-band). Furthermore, many in-situ GNSS campaign can contribute to these studies. This huge amount of data is opening new perspectives to meteorology with emphasis on accurate local forecasts, especially of extreme events, and nowcasting. Government and agencies are increasingly demanding accurate meteorological information as a source in their decision making processes. Nevertheless in the majority of cases these practitioners are not experts nor in meteorology and assimilation procedures, nor in the processing of EO data. Therefore, the authorities need specific tools that enhance their decision making processes by facilitating the understanding and management of meteorological observation and prediction products.

The major requirements for a tool that manages meteorological observations and forecasts consist on handling spatial data (time series of 1D, 2D and 3D spatial data) and offer specific analysis and visualization capabilities of the field of meteorology and the possibility to handle information on specific meteorological events and retrieve data from meteorological databases. A key step is the definition of specific features that can help the extraction of information from meteorological data.

In this talk we will present:

1) 2D and 3D datasets of atmospheric water vapor derived by InSAR and GNSS techniques;

2) Assimilation InSAR and GNSS data into a Numerical Weather Model

3) Features which can be extract from meteorological datasets

4) Tools for the visualization of meteorological information based on a web browser

GEOGRAPHIC DISTRIBUTION OF BIG DATA PROCESSING BY SPACE-FILLING CURVES

Keywords: Big Data, scheduling, space-filling curves

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A core element of Big Data methodologies is the migration of processing tasks towards the storage subsystems that support relevant datasets, in order to minimize expensive migrations through networks with limited capacity. This element is particularly important for the analysis of extended time series of remote sensing data products, each frame of which can easily exceed a GByte of volume. This contribution describes the strategy employed towards this end in a distributed data processing facility dedicated to the monitoring of critical basic good distribution infrastructures (aqueducts, electricity networks) by multi-temporal remote sensing. The proposed approach centers on instantiating a number of geographically focused, specialized queues consuming processing tasks each of which concerns data elements in a distributed, diverse repository of products that is organized globally by the exploitation of scheduling by space-filling curves.

DEEP LEARNING – A INTERDISCIPLINARY VIEW OF LEARNING ALGORITHMS FOR REMOTE SENSING IMAGE ANALYSIS

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Machine learning and especially Deep-Learning methods have revolutionized many fields related to vision in the last few years through a series of groundbreaking advances. Learning systems, such as Convolutional Neural Networks (CNNs), have proven to be a leading approach when considering learning through labeled examples (supervised learning) and have result is a series of important milestones.

Considering the different innovation currently achieved by CNNs, probably their most important contribution is related with their intrinsic property of transfer learning which allows them to "reuse" their gained knowledge over a vast set of different vision problems with great success. Concretely, as an example one can refer to the important classification gains one can achieve when classifying remote sensing data while using a pre-trained CNN network (prior knowledge) that has extended knowledge over the classification of a large number of dog and cat breads.

In this talk we will focus into the interdisciplinary nature of Deep-Learning methods and discuss how fields such as Remote Sensing and Astronomy can benefit from such systems without being "distracted" by the CS aspects of such approaches. Furthermore, we will discuss important breakthroughs and intriguing properties of such systems in the context of Supervised and Unsupervised learning.

The goal of this talk would be to motivate the participants on the importance of Deep-Learning systems and give the opportunity to understand some of their important properties without extended studying of the respective literature. Directions for further reading and software solutions will be also given so that interested researchers can dive deeper into current advances.

TEACHING ADVANCED METHODOLOGY TO ASTRONOMERS

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The formal curriculum of astronomers is badly deficient in coverage of statistics, applied mathematics, and computational methods. Yet much of their research activities are in these areas. The problem is exacerbated by the growing important of telescopes producing Big Data where both the data reduction and the science analysis require advanced methods. I describe our efforts to ameliorate some parts of this educational deficit. We have over a decade experience with short hands-on workshops in astrostatistics that has reached perhaps 10% of the world's astronomical community. Several textbooks are also now available. Astroinformatics education is still in its infancy with additional opportunities and challenges.

SHAPING THE FUTURE OF ASTRO- & GEO-INFORMATICS EDUCATION

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Future Nobel Prizes will be buried in data, and interdisciplinary research will be key to making new discoveries and generating insight. Astronomy and geoscience are excellent examples of disciplines undergoing fundamental transformations due to space-based and ground-based sensor networks generating Big Data. A new breed of astroinformatics and geoinformatics scientists is needed to tackle the growing spectrum of scientific and computational challenges.

Unfortunately, many of today's curricula have myopic views when it comes to truly interdisciplinary programs. In addition, scientists conducting interdisciplinary research are facing a variety of obstacles that can make the pursuit of such careers unattractive.

It hasn't always been this way. To identify potential issues and possible ways forward, I propose the following Gedankenexperiment to initiate a discussion: Consider the example of Carl Friedrich Gauss who made contributions to number theory, algebra, statistics, analysis, differential geometry, geodesy, geophysics, mechanics, electrostatics, astronomy, matrix theory, and optics. Now substitute or add fields related to today's BigSkyEarth challenges and adapt to our current context. What institutional environment would be needed to foster such breadth and creativity? Where and what would students study? How to address funding of interdisciplinary research and education? How to improve career development? Are we open-minded enough?

Learning from distinguished academic ancestors might help us find a way forward. I will share my own interdisciplinary teaching experience and outline suggestions for Astroinformatics and Geoinformatics education.

DATA MANAGEMENT PLANS AND STANDARDS FOR SPACE DATA: HOW TO TRAIN FUTURE SPACE DATA PROVIDERS AND USERS

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In early space research, data management plans were largely unknown, as soon as a space instrument was put in orbit, it provided data which were received at ground receiving stations and rearranged as time tagged raw data to be interpreted in terms of the scientific parameters to be determined, these were then published with a quality control exercised mainly by the peer review process.

Several failures of the early seventies led to consider standardisation as for example, mechanical data format programmers could be put in an unknown position by launch vibrations or astronaut unrecorded errors. This led to several attempts leading to a current situation described in the present communication. The following points could lead to a training module in these subjects:

- description of the EU INSPIRE directive on Data Specification on Coordinate Reference Systems together with its related ISO standards.
- CCSDS standard for raw space data,
- similar international norms for space and space science data: data formats for distribution files used in space science, earth observation and operational earth observation satellites.
- Format and norms used by the international WDC's (world data centres)
- Evolution of these different standards and necessity of migration processes for data preservation.

This module would continue by the description of a Data Management Plan as it is now required in NASA proposals, ideally, a DMP is a formal document, usually prepared at the start of a project, that describes what data should be preserved and how. At early proposal level, it is usually prepared by the owner of the project (i.e. a scientist). DMP's cover the actions taken during the project (e.g. recording of metadata) as well as the post-project management of the data. In real life, proposals are usually drafted by early career scientists under the direction of the Principal Investigator. This stresses the importance of education of the scientists to these management aspects before they begin their professional career.

The PERICLES FP-7 project by introducing the conception of semantic change leads to the concept of an Advanced Data Management Plans where scientific objectives evolve during the data lifetime as well as the different standards for data transmission and archiving. These aspects will also be presented and proposed for education modules.

Finally, the data aspects of space operations will be presented as well as applications to situations where the sensor data can only be partially transmitted due to difficult communications (distant planets, caves, even Antarctica).

HOW CAN THE EVOLUTION OF DATA MANAGEMENT SYSTEMS HELP FOR BIG DATA APPLICATIONS

Key Words: Big Data Management, Data Partitioning, Data Integration, Parallel Database Systems, Cloud Data Management Systems, Query Processing and Optimization, High Performance, Scalability, Elasticity, Hadoop MapReduce, Apache Spark, Multistore Systems

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The purpose of this talk is twofold: (i) to provide a synthetic state of the art concerning (large-scale) data management systems, and (ii) how can the evolution of these systems help for big data applications (e.g. Astronomy, Earth Observation). In this perspective, data management based on parallel and cloud systems (e.g. MapReduce, Spark, Multi-store systems) are overviewed, and compared by relying on following criterion: (i) Wealth of data models, (ii) Capability to integrate data heterogeneity, (iii) High performance, (iv) Scalability, and (v) Data availability.

With respect to the state of the art, proposed systems, and qualitative and quantitative comparative studies between Parallel DBMS PDBMS and Big Data Management Systems BDMS, we will point out: (i) Functional complementarity between PDBMS and BDMS, (ii) Lack maturity and standardization/normalization of BDMS compared to traditional PDBMS. Finally, we try to learn some lessons and point out some open issues that should be tackled to ensure the viability of the next generation of large-scale data management systems for big data applications.

SOFTWARE ENGINEERING PRACTICES FOR SPACE EXPERIMENTS

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The data analysis of a scientific space instrument calls for a systematic approach following established standards. These standards have to be made known to all researchers who plan to contribute software to a space project.

Currently, space agencies, research groups, and industry have gained a lot of experience with conventional software engineering techniques to manage the development of software components (e.g., for the handling, pre-processing, and higher-level product generation of scientific instrument data).

On the other hand, newly emerging techniques such as machine learning, data mining, and data analytics will become part of future projects. In particular, Big Data will have noticeable consequences for the development of scientific software and the related engineering concepts.

This presentation will describe current practices that have been widely adopted in the community and will try to sketch the potential impact of the above-mentioned newly emerging techniques with respect to the education and training of young professionals.

MEANS OF COLLABORATION BETWEEN HE INSTITUTIONS AND THE RAPIDLY GROWING IT INDUSTRY IN SERBIA

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The rapidly growing IT industry in developing countries of several Eastern European countries is providing a strong support to the local economy. In Serbia alone, some 2,500 IT experts at BSc level are hired annually and it has been estimated that in the following 5 years that number will increase to 20,000 per year. A starting hourly rate of a programmer in the city of Novi Sad, for example, is 10 EUR/h, which is significantly higher than the national minimum wage of 1.27 EUR/h or even the national average in 2016 of 2.04 EUR/h (this average includes highly-paid software engineers). Since 2002 Novi Sad has witnessed a staggering boom of newly opened IT-oriented SMEs. And the trend will apparently only ascend. It is estimated, that 80 % of the online gaming software is produced by companies from Novi Sad today and that there are presently at least 10,000 opened positions for trained software engineers in a city with the population of only 300,000. Appealing working benefits, salaries significantly above national averages and promise of immediate employment have opted many young minds for software engineering careers. But all this unbalanced growth had to come at a price. The relocation of large portion of the population to the IT sector has to be done at the expense of non-IT professions. Hence, a huge misbalance at the labour market is expected in the following years.

Particularly affected by this shift are higher education institutions, since a significant portion of the young population is now poorly motivated to pursue education beyond the BSc level. A surprisingly large vacuum is created in the educational sector at the MSc and PhD levels even in those fields which are directly related to the IT, e.g. electrical engineering or natural sciences. Less students means less research opportunities, less projects and inevitably fewer successor to teaching positions. And it is important to understand that in the previous decades of economic crisis educational apparatus grew rapidly as more young people preferred study – even prolonged one – to unemployment. This tendency combined with the pay-per-student policy of the Ministry of Education has forced many of the amassed departments to evolve and adopt more IT-oriented curricula in an attempt to salvage their jobs and salary levels. In some extreme cases they went as far as to create almost entirely software engineering based courses at faculties for medicine, agriculture, mechanical engineering, economy etc. giving them hybrid and quite obscure names. Many companies from the IT industry are now seizing the opportunity to form provisional and loose public-private partnership with desperate HE institutions and secure the necessary labour force. They offer, on the other hand, the necessary minimum enrolment in each study year to keep the financial wheel spinning for the partnering HE institution. But, the common yet frequently overlooked drawback of this alliance and the uncontrolled evolution is the creation of many ad-hoc “mutant” curricula, undoubtedly lacking quality and being far from any good practice in higher education sector of more developed countries.

On the other hand, the IT industry sector perpetually faces an imminent and omnipresent threat. The fact is that most software companies in Serbia perform very little beyond mere outsourcing. There are only several examples of original products and disruptive technologies being launched in the past 14 years. This makes majority of the companies and their numerous

employees easily replaceable on the global market, and completely exposed to any future economic crisis.

In an attempt to find a solution which could solve a part of the problems for both sides, the Centre for Collaborative Research (CCR) has been founded at the University of Novi Sad – Faculty of Technical Sciences (FTS). This was a logical follow-up of the substantial entrepreneurial activity at the FTS, which spun-off 115 SMEs in the past 20 years with an annual turnover above 100 million EUR. This means that there is a natural and close link of the Faculty to the regional IT sector. Yet this bond has predominantly being exploited for recruitment purposes as was the case with many other HE institutions. In the domain of research the potential is insufficiently exploited. Past joint research ventures were fragmented and inadequately coordinated in spite of the prospective benefit for both sectors. The CCR has been formed with a precise aim to develop, foster, perform and promote synergy with the local IT industry through synchronized research activities of the highest quality. The goal is to promote investments into the segment of education that should be in the closest relation with the industry and to bring the IT sector a much needed excellence in business development.

One of the key strategic targets of the Centre is to constantly evolve its understanding of technological needs of the IT industry through direct contacts with professionals and companies. This will help identify topics of applied research that would satisfy the needs of public and private sector and conduct research relevant for the industry. Although the concept itself is not novel, what singles out our Centre from other centres in continental Europe is the business model by which the activities will be managed. The model foresees that individual companies participate in financing the research on voluntary basis and a have a saying in directing that research proportionally to the amount of money invested. The concept has been previously presented before the National Science Foundation (NSF) of the USA, and the Board of the Industry/University Cooperative Research Center for Advanced Knowledge Enablement (I/UCRC) operating at the Florida Atlantic University and at the Florida International University. The Board and the NSF approved opening of the CCR as an international division of the I/UCRC with full access to its intellectual property and ongoing projects. This would enable our local IT companies a visibility on the global scale and access to contracts far outside their current reach with a fair prospect to overcome the gap of concurrent performance on the international market.

The activities of the CCR will not be able to considerably alter the present (undesirable) form of public-private partnership. But we will strive to secure – to a certain extent – the essential support to advanced levels of higher education and research at our Faculty. By harnessing this opportunity and the present market setting we are looking forward to maintaining better control over the science-industry cooperation and become a driving force behind its future prosperity.

INNOVATION AND VALUE PROPOSITION IN BIG DATA – HOW ENTREPRENEURS AND SMES BENEFIT FROM ASTRO- & GEO-INFORMATICAL KNOWLEDGE

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Data is the new Oil of the next Technology revolution. Big Data analytics and delivery are equivalents to Oil refineries and petro-chemistry businesses which adds the value of the crude oil into much more expensive products. Despite of recent research and developments in the field of Big Data, the Business Models for innovation in Big Data analytics especially in Astro- and Geo-Informatics are still to be developed, optimized, implemented, and validated.

Entrepreneurs and startups who want to expand their contributions in Big Data, frequently asks the questions such as: What are the Business Models and added values? Who are the end-Customers and Market Segments of Big Data Products? How to reach a sustainable/competitive Business Model?

As of today, large, mature companies such as Google, Amazon and Apple have a close connection to their customers' activities, and are looking for methods to monetize their own big data. They try to define sustainable solutions to capture innovative revenue streams to effectively compete even in the future. The question is what's behind their business models and what market niche is left for other companies, specifically entrepreneurs and SMEs who want to enter this business.

In this paper, we study the state of the art development in Big Data Innovation and review recent development and success stories. We also review the challenges and opportunities of Big Data innovation. Various Business Models and Value Propositions will be also studied, which are based on delivering data, information or solutions. In each case, the key activities and resources, customer relationships and channels as well as the market segments will be described in detail. Also there will be recommendation how the academia can get closer to and partner with the industry in this regard.

FUNDAMENTALS OF MACHINE LEARNING FOR PREDICTIVE ANALYTICS

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Machine learning is often used to build predictive models by extracting patterns from large datasets. These models are used in predictive data analytics applications including price prediction, risk assessment, predicting customer behavior, and document classification. The large volumes of data being generated in earth observation and astronomy make it ideal for the application of machine learning techniques. This introductory lecture offers an overview of the most important machine learning approaches used in predictive data analytics, covering both theoretical concepts and practical applications.

BIG DATA ERA IN ASTRONOMICAL EDUCATIONAL ACTIVITIES IN ARMENIA

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Big Data Era in Astronomy (e. g. Astsatryan et al. 2016) also puts requirements for appropriate educational activities. Armenia is a country with rather high level of professional astronomy (Byurakan Astrophysical Observatory (BAO) with its famous surveys, Yerevan State University (YSU) and other research institutions), as well as astronomical education is being promoted (Armenian pupils are rather successful at international astronomical Olympiads). Astronomy education includes school astronomy, local and international astronomical Olympiads, Galileo Teachers Training Program (GTTP), university level astronomy (B.Sc. and M.Sc.), Ph.D. studies at BAO and YSU, local and international summer schools organized in BAO, participation of the Armenian students in the international summer schools, etc. The present young generation gradually finds more and more attraction in astronomy and space sciences. In addition, the knowledge of computers and Internet is their typical difference from the previous generations of students and it is important to keep the astronomy education up-to-date and introduce interactive, online and virtual methods in teaching.

DVDs Astronomy for schools and Astronomy for students prepared for the schools and university students, respectively, serve as a good basis for both classic and modern knowledge. These DVDs contain a large number of software and tools, interactive textbooks and are being regularly distributed to students at summer schools and school teachers at GTTP meetings. The Armenian Astronomical Society (ArAS) gives strong importance to the education, such as by placing educational materials on its webpage, organizing ArAS school lectures by professional astronomers, producing and publishing educational materials, etc.

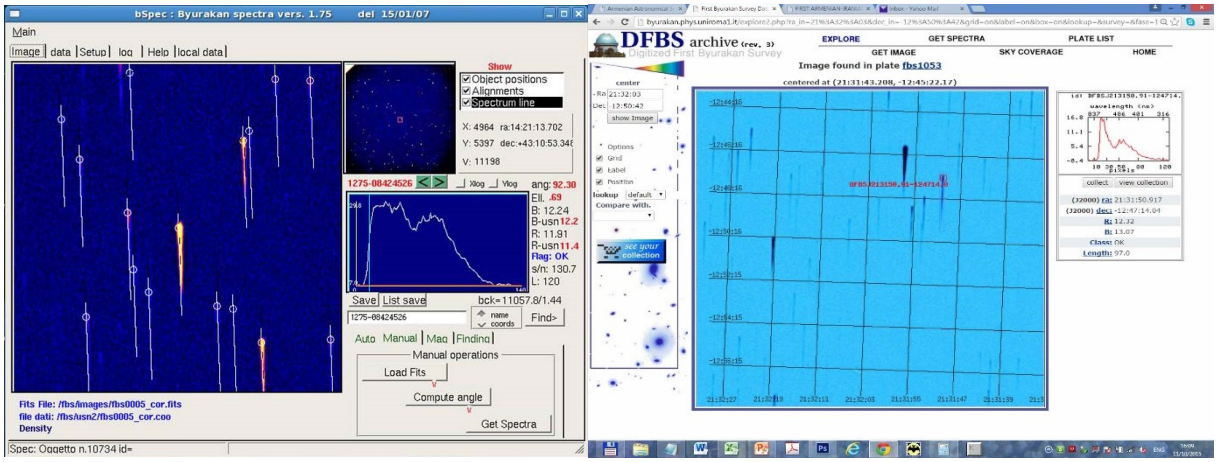

Fig. 1. DFBS extraction and analysis software bSpec and DFBS web interface used for training of students.

The main development by the Armenian astronomy related to computer science is the Digitized First Byurakan Survey (DFBS; Mickaelian et al. 2007; Massaro et al. 2008) and its software. It is also being actively used for training of students in Astroinformatics and VO skills. DFBS extraction and analysis software bSpec and DFBS web interface used for training of students

are given on Fig. 1. Examples of DFBS fields with two fast asteroids for training of students in finding moving objects by means of the software SkyBot are given in Fig. 2. The Armenian Virtual Observatory (ArvO) was created in 2005 based on the DFBS and some other developments (Mickaelian et al. 2016c).

A special emphasis is put on inter-, multi- and transdisciplinarity in astronomical education by promoting fields in tight collaboration with computer science, such as Astrostatistics and Astroinformatics, virtual observatories, computational and laboratory astrophysics, etc. All this is also in frame of the IAU Strategic Plan Astronomy for Development.

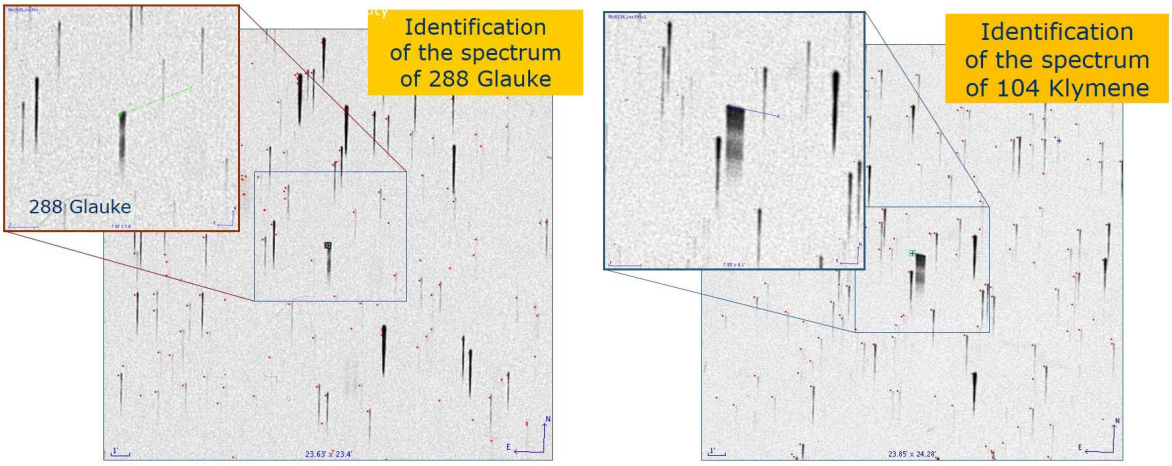

Fig. 2. DFBS fields with two fast asteroids for training of students in finding moving objects by means of the software SkyBot.

The above mentioned subjects are being actively taught at Byurakan International Summer Schools (BISS) for young astronomers held once every two years (regularly organized since 2006), Byurakan Summer Schools (BSS) for Yerevan State University (YSU) physics students since 2005, Byurakan Science Camps (BSC) for school pupils since 2014, ArAS school and public lectures, NASA Hackathons, and other events. BAO young astronomers participate in international summer/winter schools organized by Euro-VO, NVO and other related ones.

Armenian young astronomers are involved in all related projects, particularly in the joint project with the Institute of Informatics and Automation Problems (IIAP); the Digitized First Byurakan Survey (DFBS) database has been installed on Armcluster supported by IIAP. ArVO is an active member of International Virtual Observatory Alliance (IVOA). Armenia is also part of the International Planetary Data Alliance (IPDA), ICSU World Data System (WDS) and other related organizations. Armenian astronomers, including the young ones, regularly participate in IVOA interoperability meetings, ICSU WDS and CODATA Conferences, Astroplate Workshops, etc. In 2016, two young Armenian astronomers participated in COST BigSkyEarth Action Training School and presented their projects.

We have also organized several meetings, where big data in astronomy were reported and discussed, such as the meeting Relation of Astronomy to other Sciences, Culture and Society (RASCS, 2014), the symposium Astronomical Surveys and Big Data (2015; Mickaelian et al. 2016a), actively participated in Computer Science and Information Technologies (CSIT) Conferences organized by IIAP in 2009, 2011 and 2015 (e. g. Mickaelian 2015).

In 2015, we have started a project on BAO Plate Archive Digitization, creation of Electronic Database, and Scientific Usage (Mickaelian et al. 2016b), where 11 young researchers are involved and get reliable practice in Big Data and Astroinformatics knowledge. All this assures that in the future these young astronomers will promote the developments related to big data in astronomy/astrophysics.

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HOW TO GROW AN ASTROINFORMATICIAN

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The current astronomy is becoming the data driven science characterised by the real tsunami of data flowing from every observational and theoretical simulation project. To extract the new knowledge from petabytes of enormously complex distributed databases and archives requires a new methodology called Astroinformatics, integrating advanced statistics, data mining, machine learning and software engineering into the traditional astrophysical disciplines. This naturally generates needs to educate a new type of scientists experienced both in his/her original discipline and handling the big data sets in massively parallel cloud environment, experts in modern Bayesian statistics and machine learning methods and good programmers and software engineers with knowledge of Virtual observatory tools, Python, GPUs and GRID and cloud infrastructure.

Unfortunately, so far there are no such curses to grow the so called data scientist, or astroinformatician at majority of universities, so the only viable solution is to teach the computer scientists astronomy or the astronomers the computer science. The author has an experience with both types of student's skill enhancements, leading a number of Bachelor's and Master theses at several Czech faculties of informatics and giving curses about Virtual observatory for astronomers at several faculties focused on Astrophysics in Poland, Turkey and Czech Republic, as well as collaborating on joint grant projects on astroinformatics with pure informaticians and computer scientists.

The main problems and bottlenecks of such interdisciplinary projects will be identified with number of examples of hardly recognised tiny details which were crucial for the success of the projects due to their different accent in both cultures (e.g. the selection of journal for publication, type of conference for presentation , etc.).

THE NEED FOR A NEW GENERATION OF METEOR DATA SCIENTISTS

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Meteors have a fascinating diversity of importance in various fields of astronomy, aeronomy, geophysics, evolutionary biology, planetology and science popularization. Historically, it has been difficult to explore meteors by high-resolution high-sensitivity imaging or spectral detectors because of meteors' large angular size on the sky and random appearance. However, over the last couple of decades technological advancements in observational techniques have yielded drastic improvements in the quality, quantity and diversity of meteor data, while even more ambitious instruments are about to become operational. This empowers meteor science to boost its experimental and theoretical horizons and seek more advanced scientific goals. We review some of the developments that push meteor science into the Big Data era that requires more complex methodological approaches through interdisciplinary collaborations with other branches of physics and computer science. We argue that meteor science should become an integral part of large surveys in astronomy, aeronomy and space physics, and tackle the complexity of micro-physics of meteor plasma and its interaction with the atmosphere.

NEW CHALLENGES IN NETWORK ANALYSIS - FOR STUDENTS, PROFESSORS AND INDUSTY

Authors: Ognyan Kounchev (1)

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In the lecture we discuss some recent advances in the area of Network Analysis, in particular the development of new tools of Spectral Analysis for exploring massive amounts of Big Data structures. Although the new developments in this area require more advanced mathematical tools, the experience shows that students are learning the new approaches really fast, and this is very encouraging. However the speed of the new developments shows that quite big is the delay in the spread of new methods in the industry, hence one needs a special curriculum for a post-diploma education of people who have left university a decade ago.

FROM ASTROPHYSICS TO SME

Authors: Uroš Kostić (1)

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At first sight it may seem completely irrational to quit an academic job in astrophysics and switch over to industry, let alone start your own business. However, by presenting a personal view on the whole transition, I hope to show that, when it comes to usefulness of respective education (e.g. data analysis, simulations, software), the two "worlds" are not that far apart. I will also briefly talk about different problems that we are working on at the moment, and point out how they relate to research I used to do in academia.

INFORMATICS IN ARMENIAN SCHOOLS AND THE BACKGROUND FOR ASTROINFORMATICS STUDIES

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Today's technologically developed era is renowned by its strict require of basic IT knowledge and the desirability of insight in computational sciences. Sufficient computer literacy is one of the problems of today's society. Armenia is one of the countries to perceive this and take actions towards the development of knowledgeable society. Many measures are meant to educate the youth, such as mandatory classes of informatics in the schools, a diversity of facilities for extracurricular activities in this field and both the national and the international Olympiads.

Teaching informatics in the schools contributes to the formation of the modern worldview of the young society and creates the necessary conditions for the introduction of the information technologies in educational process. Those studies contribute to the increase in the productivity of the digestion of the study material. From this point of view the computer is seen as a gadget to search for information, receive it, modify and save. Thus, informatics is an essential component not only for the natural sciences, but also for the humanities. Informatics is being taught from the 6th grade[1]. In the high school, the program is made taking into account the streaming-oriented education. Each stream is given the software package that will be useful to students in both studying at the university and starting their career. In the stream of the natural sciences informatics is taught in the form of programming (C++, SQL, HTML, Microsoft office etc.). Humanities are supposed to be taught in such packages, which are suitable for administration (Microsoft office, HTML, Internet etc.) and the program of the general stream aims to develop necessary computer skills to meet the requirements of life and the future business activities through the study of popular applications (Microsoft office, HTML, Internet, algorithms etc.)[2].

Furthermore, except the national system, there are many facilities for more interested and creative students where robotics, animation, game development, web development and digital media are being studied (TUMO[3], Armrobotics[4]). These are some kinds of after-school environment where thousand of students are in charge of their own learning. They are guided by skilled educators and mentored by professionals. These facilities are aimed to expand young people's horizons and give them the resources to achieve their full potential and help to acquire the 21st century skills they need to succeed in life. Also, the facilities contribute to the development of the abovementioned fields in Armenia and promotion of the establishment of the organizations in those fields. Additionally, many private schools are open for the lessons of informatics in the desired categories.

Finally, Armenian youth is active in the International and National Olympiads of informatics. Armenia started participating in the IOI in 1996 in Hungary[5]. Our students won 1st medal (bronze) in 2002. Since then they returned from an IOI with at least one medal. For us especially significant are IOI'2005 when Vahe Musoyan won gold medal, and IOI'2014 when all four students won medals (2 silver and 2 bronze). So far, Armenia has 1 gold, 4 silver and 20 bronze medals. The Ministry of Education and Science holds the National Olympiads among school students. They are held in three stages and the winners of the final stage are eligible for the IOI.

Armenian students are rather successful in International Astronomy Olympiads (IAO) as well[6]. They participate in IAOs since 1996 and in total they have won 9 gold, 5 silver and 19 bronze medals. Since 2014, they also take part in International Olympiads on Astronomy and Astrophysics (IOAA)[7] and also have won a number of medals.

There are many students that have achieved success in both Informatics and Astronomy Olympiads, including medal winners of both such international Olympiads. Even though the inter- and multi- disciplinary sciences are not well developed in Armenia (and especially Astroinformatics) but these students are perfect candidates to grow and become professionals in this field. The collaboration between the Byurakan Astrophysical Observatory (BAO) and the Institute of Informatics and Automation Problems (IIAP) (both are affiliated to the Armenian National Academy of Sciences) led to new developments in Astroinformatics and MSc and PhD diplomas defended in co-supervision of students by an astronomers/astrophysicist and computer scientist. BAO encourages young people to be involved in these studies and further research aimed at implementation of modern methods in astrophysics in the Big Data era. These students are also involved in educational activities running in Armenian schools related to both Informatics and Astronomy.

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BIG DATA, CLOUD AND MACHINE LEARNING AND THEIR IMPACT TO EDUCATION

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The Moore law of doubling computer transistors in every 1.5 year, which started in 1965 has exponential impact on technology. Wide spread and adoption of technology produce a lot of data, named Big Data, doubling the data volume on each 2 years. The infrastructure to support enormous amount of data is the cloud which is the next step in the computer evolution making data and processing available everywhere and anytime, providing "unlimited" data and processing capabilities. The main ingredients, big data and the cloud made renascence in machine learning (ML) and artificial intelligence (AI). The cloud and big data are in enhancing already established methods like artificial neural networks into deep learning or convolutional neural networks making breakthroughs in image recognition and other fields. ML and AI are a game change, as some of the products are on the way like autonomous driving, advanced robots, etc.

The software is following the hardware rapid development producing solutions that are becoming mainstream in only couple of years. For example, Hadoop, Map Reduce, MongoDB as big data flagship software, web/cloud software frameworks Angular.js, Node.js etc, are getting a momentum making possible to develop a services that are scalable by design and support millions of users. New concepts like DevOps are emerging making small teams capable of producing applications used by millions of people (WhatsUp).

Education is trying to keep pace with technology. The internet is making widespread of available learning materials often for free. Now it is not a question, do I have access to the library, or do I have the right book, but instead do I want to learn, and which material/book to use. To focus more on the subject, if the question is, do we need computers and programming knowledge in the interdisciplinary research, my opinion is definitely yes. Learning computers and basic coding should be learned by everyone, starting from primary school as most of the research done nowadays heavily rely on computers for modeling, data storage, processing and analysis. If we get more people into Science, Technology, Engineering and Mathematics (STEM) it would benefit the society as whole.

FROM BIOINFORMATICS TO ASTROINFORMATICS CURRICULUM : THE FRENCH EXPERIENCE

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In the early of 90's, Biology and Computer Science were faced to the process of knowledge discovery in very large biological data. An opportunity was then given to University to elaborate new curriculum devoted to people that can collect and analyze biological data, as well as understand the obtained results.

In this talk, I will explain how during two decades the French Bioinformatics curriculum has been gradually devised, resulting generally in two types of programs : one for computer scientists and another for biologists. I will then discuss the insights of those programs, and try to draw a parallel with Astroinformatics curriculum, especially in the context of Big Data Era.

DATA SCIENCE EDUCATION: TRENDS AND CHALLENGES

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Data science is an interdisciplinary field aimed at extraction of knowledge and insights from data, including very large data sets often referred to as Big Data. Recent technology advances made it possible to collect increasingly large data sets with a high rate of acquisition, opening a host of new challenges and opportunities in diverse application areas. As the volume of data is increasing rapidly, it is now expected that by 2020 there will be more than 16 zettabytes of useful data (16 Trillion GB), implying a growth of 236% per year from 2013 to 2020, according to a study "Worldwide Big Data Technology and Services 2014-2018" by IDC, a US market intelligence provider. In the early 2000s, the corporate world experienced an incredible transformation. More businesses completed transactions online. Every transaction was recorded - and by 2009, an average corporate database contained about five petabytes of data. Google started logging every search made in 1998. In 2004, Facebook started logging every interaction their users were making. The most recent trend is the Internet Of Things (IoT), and by 2020, about 30 billion objects may be connected to the IoT, compared to roughly 10 billion in 2013. The amount of data generated will continue to grow tremendously. In 2015, 90% of world data has been created in the previous 12 months, which shows the speed of the data growth. Data has truly become an asset - one that can create significant competitive advantages and drive innovation, increase competitiveness, and create tangible social impact.

Due to government and industry pressing need for Data Science expertise, the market demand for data scientists has soared in recent years. Such a high demand requires appropriate education programs at various levels, from undergraduate, graduate to postgraduate level. The number of data science programs being offered grows quickly. Currently, a majority of data science programs is offered at graduate or postgraduate level due to the fact that the demand comes from adult students trying to compete with younger people, or to change profession.

On of the trends driving demand and development of data science area is a concept of open data. Open Data is the concept that some data should be freely available to everyone to use and republish, without restrictions from copyrights, patents or other mechanisms of control. There are many sources of open data including science and government. Institutionally, the concept of open access to science data was introduced with the formation of the World Data Center in 1958, now called World Data System, which is established by the International Council for Science in 2008.

Open data in government is motivated by the idea that government information should be available to the public as machine readable open data in order to support government transparency, accountability and public participation. Furthermore, this could support economic growth and technological innovation by enabling companies to develop tools and services using open government data. Many countries support such views by starting open data portals such as data.gov initative, data.gov.uk platform, Open data in Canada, or Japan Open Data Initiative. Such initatives typically establish open data web sites where hundreds of databases are available for public access. Recent trends in Open data are that not only more and more data becomes available with time, but also that there is a shift from just providing data to more sophisticated efforts that let the public actually use Open Data without requiring advanced analytical or coding skills.

ALERTSIM - SERBIAN CONTRIBUTION TO LSST

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I will update the audience on the status of the simulator of alerts for the LSST. AlertSim is built by Belgrade LSST group and will provide a significant resource for testing CEP engines/alert brokers in dealing with large quantities of data generated from LSST simulations. Current version of AlertSim uses most of the LSST simulation capabilities (access to the Operation simulation runs, Catalog simulations). In the next few months first end-to-end simulations (from OpSim to CatSim to Galsim/PhoSim to LSST STACK to ImDiff source catalog/table) will be generated and AlertSim will be simply plugged in to produce alerts out of those simulations and give an astronomical community a sense what to be expected as Level 1 product in LSST era.

VLF REMOTE SENSING OF THE LOWER IONOSPHERE AND REAL TIME SIGNAL PROCESSING

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In the past few years, we study the influence of solar perturbations on the terrestrial ionospheric D-region by analyzing the amplitude and phase time variations of very low frequency (VLF) radio waves emitted by VLF transmitter all over the world and recorded by the AWESOME and ABSPAL receivers in Belgrade in real time. Naturally, there is a need to process and store these huge amount of collected data. Here, we will try to present and describe our steps in real time signal processing, central database storing and its current stage.

ANALYSES OF ELF/VLF/LF RADIO WAVE VARIATIONS DURING THE METEOR SHOWERS

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As a part of the atmosphere the ionosphere is under permanent influence of different natural perturbers located in the outer space and terrestrial layers. In addition, the human activity, enabled by development of modern technology, affects its characteristics. Consequently, the ionosphere is a medium of a highly complex nature concerning numerous physical, chemical and geometrical features that govern its versatile dynamics on various spatial and temporal scales.

Considering ionospheric response to particular event, detection of ionospheric variations can be divided in two groups:

First, in the case of the sufficient strong changes in plasma parameters after beginning of perturber influence we can reliably link recorded ionospheric reaction and the observed event.

Second, in the case of the weak plasma disturbances it is very hard to prove that a particular perturbation, observed close to the analysed event, is related to it because of very similar properties of perturbation induced by numerous phenomena.

Examination of differences in weak ionospheric variations induced by different phenomena very often requires much better measurement performances, like for example time resolution, than in the first case. Also, statistical analyses are needed for research of different properties of phenomenon influence on the ionosphere. For these reasons, the used collected data can form big databases and investigations based on them required knowledge and implementation of tools for data processing. Consequently, the relevant research must be based on collaboration of scientists, engineers and experts for work with databases.

One of the phenomena that can be included in this group is meteor impact in the atmosphere. Namely, the previous studies indicate the possible ionospheric reaction induced by meteors (Rault, 2011) as well as the emissions of electromagnetic waves (Keay, 1992, Zgrablić et al., 2002) during their pass through atmosphere.

In this study we present experimental method for detections both of these appearances based on ELF/VLF/LF wave measurements and analyse possible detections of considered disturbances.

ELF/VLF/LF RADIO RECEIVER.

In Institute of Physics in Belgrade it is located AWESOME (Atmospheric Weather Electromagnetic System for Observation Modeling and Education) extremely low, very low and low (ELF/VLF/LF) frequency radio receiver which operate since 2008. It has two independent loop antennas set in NS and EW directions.

The work of this device is based on two types of measurements:

1. Narrowband monitoring of VLF and LF signals emitted by transmitters located worldwide, and

2. Broadband monitoring of electromagnetic waves in frequency range between about 1 kHz and 47 kHz.

Narrowband monitoring relate to the low ionospheric observation. Namely, although both natural waves and signal emitted by transmitter at considered frequency are detected the last dominate and practically recorded variations reflect changes in the low ionosphere where these signals are reflected. In these observations global experimental setup contains numerous transmitters and receivers (they can simultaneously monitor signals from several transmitter – 15 in our case) that allow monitoring a large part of the low ionosphere and, because of high time resolution (it can be 1 ms for our device) of recorded data (signal amplitude and phase), detection of different sudden and unexpected events. Depending on the number of monitored signals and time resolution size of recorded data could be over 10 GB per day.

Broadband observations are based on detection of magnetic field amplitude with time resolution of 100 kHz. Using short-time Fourier transform (STFT) the recorded data can be processed and present as spectrograms for frequencies of electromagnetic waves below 50 kHz. The data set on both two antennas is ~32 GB per day. Detail explanation of this measurement and data processing is given in Cohen et al., 2010.

ANALYSIS OF WAVE AMPLITUDE VARIATIONS IN PERIOD OF PERSEID METEOR SHOWER IN 2016.

Although the effect of individual meteors to the low ionosphere is weak, number of these reactions is large during meteor showers which allow statistical analyses for relatively short time period. In this study we analysed perturbations in electromagnetic wave intensity, received by AWESOME receiver in Belgrade during the Perseid meteor shower in 2016. We extract several shape types of sudden variations in amplitude time evolutions. The detail study of detected variation properties required statistical analysis, implementation and further development of signal processing and, finally, comparison our collected data sets with those related to the independent detection of meteor impact. In considered observation this research is multidisciplinary: it is connection of geophysical and astrophysical studies based on processing of data obtained in measurements of natural and telecommunication signals and it will be in focus of our upcoming research.

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ASTROINFORMATICS IN BULGARIA

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We describe the Wide-Field Plate Database (WFPDB, www.wfpdb.org) as a basic source of data for the wide-field astronomical photographic plates, obtained with professional telescopes worldwide, in a context of the development of the Astroinformatics resources.

The WFPDB consists of four parts: Catalogue of Wide-Field Plate Archives; Catalogue of Wide-Field Plate Indexes, Data Bank of Digitized Plate Images, Links to online services and cross-correlation with other needed catalogues and journals. Practically the WFPDB is a unique wide-field telescope, giving access to the photographic astronomical observations, done systematically in the period 1880-2005. The database contains wide-field plate archives metadata from all over the world. The data including is done in the way to present the most precise data for the wide-field plate archives and their contents. Up to the moment the metadata for ~ 600 000 plates, some plate previews (jpg), plate logs and envelopes are at disposal. A special attention on the plate archiving is paid on some plate collections in Germany, USA, Ukraine, Romania, Hungary, Armenia, Belgium, Serbia, etc., where with the help of our working team and the efforts of astronomers, networking and information technology specialists, and librarians, the process of plate archiving is actively running.

The processing of large amount of data coming from the digitized astronomical plates put the requirements to the working team of the WFPDB for using the Astroinformatics (AI) disciples. Having in view that the area of AI has emerged as an interdisciplinary area of Astronomy and modern Information and Communication Technologies (ICT), based on the modern Internet developments, four institutes of the Bulgarian Academy of Sciences (BAS) working in these areas, launched a joint project called “Astroinformatics: signal processing and analysis of digitized astronomical data and web-based implementation” in 2009. The project aimed at the development of the necessary methods and techniques. As a truly interdisciplinary area AI in Bulgaria has arisen from the need of ICT methods for preservation and exploitation of the scientific, cultural and historic heritage of astronomical observations.

Now several BAS institutes, as well as Sofia University (SU) and New Bulgarian University (NBU) collaborate for offering PhD programs in this area. Some master theses were already done by graduate students in the SU Faculty of Mathematics and Informatics and in the Department of Informatics of NBU. At undergraduate level, the training of students includes operation with big data as part of the learning process in programming, algorithms and numerical methods. Another tool for education in AI is the developing site (www.humboldtastroinformatics.net), set up for exchanging information and networking and to be a regional node for AI, establishing in such way innovative multilateral academic cooperation. The site offers also possibilities (now in preparation) for the wide public to learn and even to serve to public science through existing public portal, created dictionary, interactive blog and contacts with professionals.

ON THE RELATIONSHIP BETWEEN LONG-PERIOD COMETS AND LARGE TRANS-NEPTUNIAN PLANETARY BODIES

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In the present work we investigate the possible relationship of long-period comets with five large and distant trans-Neptunian bodies (Sedna, Eris, 2007 OR 10 , 2012 VP 113 and 2008 ST 291) in order to determine the probability of the transfer of a part of these kind of comets to the inner of the Solar System. To identify such relationships, we studied the relative positions of the comet orbits and listed TNOs. Using numerical integration methods, we examined dynamical evolution of the comets and have found one encounter of comet C/1861J1 and Eris. Furthermore, we have analyzed the values of Tisserand's constant for 1181 long-period comets regarding 156 trans-Neptunian bodies having absolute magnitude H<5.5m . There were difficulties of applying the criterion, related to the inclinations and eccentricities of the TNOs orbits. Therefore we have developed three options for overcoming them. As a result, we have found a large number of comets (>600) having Tisserand's constant values from 2 to 3. Statistical dependence between the number of such values and planetary orbits eccentricities has been established also.