INFORMATICS

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Recent Developments of e-Science Infrastructures in Armenia

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1. Introduction. The application of computers and mathematical methods for the decision of scientific and technical tasks was one of the basic tasks put in front of the Science in Armenia still in the initial period of creation of computer facilities and cybernetics. Data generation and analysis using computational methods are at the heart of all modern science and technology. New e-science [1] research methods are exploited advanced computational resources, data collections and scientific instruments. The ICT infrastructure for science is called e-Infrastructure [2] and is the elementary building block of the e-Science. e-Infrastructure is an environment, where research resources (hardware, software and content) can be rapidly shared and accessed wherever this is necessary to promote better and more effective research. Such environment integrates networks, grids [3] and middleware, computational resources, experimental workbenches, data repositories, tools, instruments, and the other operational support that enables global virtual research collaborations.

The main aim of the article is to introduce the recent developments of e-science infrastructures in Armenia dedicated to the provision of a sustainable national infrastructure for the support of advanced research activities in Armenia. The article introduces not only the overview of e-infrastructure, but also the research teams and advanced services using such infrastructures in Armenia.

2. E-Infrastructures. Armenian e-infrastructure is a complex national IT infrastructure consists of both communication and distributed computing infrastructures. The infrastructure is operated by the Institute for Informatics and Automation Problems (IIAP, http://iiap.sci.am), which is the leading ICT research and technology development institute of the National Academy of Sciences of the Republic of Armenia (NAS RA).

2.1. Communication Infrastructures. Academic Scientific Research Computer Network of Armenia (ASNET-AM, http://www.asnet.am) is a National Research and Education Network (NREN) of Armenia, which was established

in 1994. ASNET-AM stimulates scientific development through innovative high-quality network infrastructures and associated services, to the benefit of Armenian higher education and research. ASNET-AM provides a network infrastructure for the Armenian research and education community by connecting more than 60 scientific, research, educational, cultural and other organizations of Armenia. Most of the sites located in Yerevan are connected over ASNET-AM's fibre at bitrates of 1 Gb/s. Other sites, including those located outside of Yerevan, are connected with wireless links via the television station. A few key sites such as the Presidium of NAS RA and the IIAP are interconnected at 10 Gb/s.

The ASNET-AM backbone consists of network communication nodes in 6 cities of Armenia, which are interconnected by fiber optics and wireless links. Each node connects the nearby scientific, research, educational and cultural organizations. The national backbone of ASNET-AM is connected to the European backbone GEANT (Pan-European Research and Education Network, http://www.geant.net) that is a part of the European and worldwide community of research and education networks.

2.2. Computation Infrastructures. IIAP also plays a key role at national level in the field of distributed and large-scale research infrastructures including Grid, Cloud and HPC.

In 2004, the first high Performance computing cluster (128 processors, Myrinet interconnection) entitled Armcluster [4] had been developed in IIAP with the 523.4GFlops performance by achieved by High Performance Linpack test [5]. Being the most powerful computational resource in the field of science and education in Armenia and in the South Caucasus region, the Armcluster constitutes the core of the Armenian grid infrastructure.

IIAP coordinates the Armenian National Grid Initiative (ArmNGI, http://www.grid.am), which is a national effort of Armenia to establish a nationwide grid environment for computational science and research. The goal of the ArmNGI is to pursue a variety of scientific users in utilizing the Grid for their applications. All these applications rely on a wide range of diverse computer science technologies composed from standard grid middleware and sophisticated high-level extensions. Now the computational resources (about 500 cores) of Armenian Grid infrastructure distributed among the leading research (National Academy of Sciences, Yerevan Physics Institute) and educational (Yerevan State University, State Engineering University of Armenia) organizations of Armenia located in Yerevan and Ashtarak cities. Mainly local scientific communities are members and use the facilities of the first Armenian national "ARMGRID.GRID.AM" VO.

The migration to the cloud computing in Armenian academic sector is already started. Small clouds based on OpenNebula and OpenStack platforms have been created. IIAP also coordinates the activities to deploy an integrated federated Cloud infrastructure in the Black Sea region (Black Sea Cloud Infrastructure, http://blacksea-cloud.net) mainly in Romania, Armenia,

3. Advanced Services. Current technology significantly accelerates the scientific problem solving process by allowing scientists to access data remotely, distribute job execution across remote parallel resources, and efficiently

manage data. Scientific workflow systems improve this situation by creating scientific gateways to a variety of technologies and automating the execution and monitoring of the workflows [6]. Several projects based on web portals are providing advanced features (workflow manager, easy deployment of services, authentication and authorization procedures, information services, etc.) for building problem solving environments or deploying software and tools for scientific communities, such as P-GRADE [7] and DIET [8]. They supply facilities for deploying new services and provide APIs for generating web portals. Several services and tools have been developed to provide value-added abilities to the target research communities using the above mentioned portal frameworks, such as:

- A single sign on integrated multi-service environment [9] with an easy access to different kind of mathematical calculations and algorithms to be performed on hybrid distributed computing infrastructures combining the benefits of large clusters, Grid or cloud, when needed.
- A portal for quantum optics technologies [10], which provides the numerical simulations and modeling of complex quantum systems in the presence of decoherence with wide applications in Photonics.
- An Interoperable scientific gateway for Parallel Geoprocessing of Satellite Image Indices [11] using spatial data infrastructures.

4. Research Teams and Applications. The main research teams in Armenia using the distributed computing and storage resources concentrated on particle physics, life sciences and computational chemistry, earth and climate, astronomy and cosmology, computational engineering and other scientific disciplines. Some developed applications that need either adequate computational or storage resources are given below:

Meteorology: The Weather Research and Forecasting numerical weather prediction model for the territory of Armenia has been implemented [12] and operational used daily, which makes possible both the understanding and the prediction of mesoscale precipitation systems and promotes closer ties between the research and operational forecasting communities.

Astrophysics: Byurakan Astrophysical Observatory of NAS RA possesses an enormous amount of astronomical information obtained during the last 60 years, on about 20 thousand photographic plates and films. The most valuable part of this information is the First and Second Byurakan Surveys with many millions of low-dispersion spectra. However, every plate with astronomical direct images or spectra is highly valuable as well and needs a safe maintenance for next generations of astronomers. All the digitized information has served as a base for the creation and development of the Armenian Virtual Observatory [13] taking into account the standards of the International Virtual Observatories Alliance.

Life Sciences: The Bioinformatics Group of NAS RA studies the molecular dynamics simulation of complex systems. Together with experimental techniques, the computational modeling, especially the molecular dynamics method has been displayed as a unique method to study the dynamical and structural features of molecular systems [14].

Informatics: The teams from IIAP engage in the following experimental and theoretical investigations: self-organized systems [15] based on the results in the theory of cellular automata and a research in statistical mechanics; classical spin glass theory [16] including the development of mathematical modeling; differential and linear cryptanalyzes of cryptosystems equivalent to SAFER+ and SAFER++ based on parallel software packages using MPI standard [17]; it was developed an optimizer-synthesizer GAROS (Graph Analyzer – Recursive Optimizer Synthesizer), which synthesizes programs for a wide class of multivariate recursive function systems [18].

Seismology: Located in one of the world's most active seismic zones, Armenia frequently experiences earthquakes. Seismic observation and seismic monitoring are vital services in Armenia. The developed seismological platform consists of seismic data server and some services. The server is the rendering layer of an integrated Grid Infrastructure that enables the research community to have access to a broad range of earthquake data from Armenian and its surroundings. This brings together distributed seismic stations to provide a single access point from which researchers can search for and download selected data and data products.

Environmental protection: The platform provides access to inventory point, stationary sources of emissions of atmospheric pollutants established to facilitate the work of writing and editing the data about the location and characteristics of these sources. The platform is based on open source GIS OpenGeo suite and is a service application for a system of numerical modeling of atmospheric pollutants.

5. International Collaboration. Armenia successfully collaborates mainly with the pan-European and regional counterparts. Armenia is a member of the following international associations and organizations in different layers including:

- Networking: TERENA (Trans-European Research and Education Networking Association, http://www.terena.org), RIPE (Réseaux IP Européens Network Coordination Centre, http://www.ripe.net), Central and CEENet (Eastern European Networking Association, http://www.ceenet.org).
- Infrastructures: HP-SEE (High-Performance Computing Infrastructure for South East Europe's Research Communities, http://www.hp-see.eu) links existing and upcoming HPC facilities in South East Europe in a common infrastructure, and provides operational solutions for it. The EGI-InSPIRE project (Integrated Sustainable Pan-European Infrastructure for Researchers in Europe, https://www.egi.eu/about/egi-inspire), as a collaborative effort, involving more than 50 institutions in over 40 countries. Its mission is to establish a sustainable European Grid Infrastructure.
- Research communities: Collaborations with the ATLAS (A Toroidal LHC Apparatus) and ALICE (A Large Ion Collider Experiment) Collaborations at CERN, as well as with the EnviroGRIDS VO aims at building environmental capacities in the Black Sea.

The communication with the European counterparts is a crucial element towards the integration into European Research Area and might create additional opportunities to increase the visibility of the region.

6. Conclusion. During the recent years, series of coordinated and complementary e-infrastructure initiatives have been developed, crucial for deploying state-of-the-art e-infrastructures in Armenia. In this paper we have described the actual status of these e-Infrastructures in Armenia, and presented a complete picture of the virtual research communities currently using them. Our goal is to focus on e-infrastructures and services that cut across a range of user disciplines and aims at empowering researchers with open online access to scientific resources, a range of facilities, networking and collaboration tools.

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Recent Developments of *e*-Science Infrastructures in Armenia

Recent years series of coordinated and complementary e-infrastructure initiatives have been crucial for deploying state-of-the-art e-infrastructures in Armenia. In this paper we have described the actual status of these e-Infrastructures in Armenia both in communication and computational levels, and presented a complete picture of the virtual research communities currently using them. The collaboration with the pan-European and regional counterparts is presented, which is a crucial element towards to the integration into the European Research Area and might create additional opportunities to increase the visibility of Armenia in computer science and information technologies.

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Հայաստանում գիտության *e*-ենթակառուցվածքների վերջին զարգացումները

Վերջին մի քանի տարիների ընթացքում մի շարք համակարգված և փոխլրացնող e-ենթակառուցվածքների վերաբերող նախաձեռնությունները վճռորոշ դեր ունեցան Հայաստանում ժամանակակից e-ենթակառուցվածքների ստեղծման համար: Սույն հոդվածը բնութագրում է Հայաստանում e-ենթակառուցվածքների ներկա վիճակը ցանցային և հաշվողական մակարդակներով, ինչպես նաև տրվում է վիրտուալ գիտական համայնքի ընդհանուր պատկերը, որոնք ներկայումս օգտագործում են նշված ենթակառուցվածքները: Ներկայացված է համաեվրոպականi և տարածաշրջանային գործընկերների հետ համագործակցությունը, որը կարևոր տարր է համաեվրոպական հետազոտական տարածքի ինտեգրման ուղղությամբ և կարող է ստեղծել լրացուցիչ հնարավորություններ Հայաստանի համար՝ առավել ներկայացված լինելու համակարգչային գիտության և տեղեկատվական տեխնոլոգիաների ոլորտում:

Г. В. Асцатрян, В. Г. Саакян, академик Ю. Г. Шукурян

**Развитие *e*-инфраструктуры науки в Армении
за последние годы**

За последние годы разработана серия скоординированных и взаимодополняющих инициатив по электронным инфраструктурам, имеющая решающее значение для создания современной *e*-инфраструктуры науки в Армении. В данной статье описываются современное состояние *e*-инфраструктур в Армении на коммуникационном и вычислительных уровнях и общая картина использующих их виртуальных исследовательских сообществ. Показана координация совместной деятельности с паневропейскими и региональными партнерами, которая является решающим фактором для интеграции с европейским исследовательским пространством и может создать для Армении дополнительные возможности быть представленной в области компьютерной науки и информационных технологий.

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