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Ž.R. 510-255-51, PIB: 02016702 302, PDV: 30/31-03951-6

Broj: 02/1-1296
Datum: 19.04.2019.

UNIVERZITET CRNE GORE

- Centru za doktorske studije -

- Senatu -

O V D J E

U prilogu dostavljamo Odluku Vijeća Elektrotehničkog fakulteta sa sjednice od 11.07.2019. godine i obrazac **D2**, sa pratećom dokumentacijom, za kandidata MSc **Luku Filipovića**, na dalji postupak.

D E K A N,
Prof. dr Zoran Veljović

ISPUNJENOST USLOVA DOKTORANDA

OPŠTI PODACI O DOKTORANDU			
Titula, ime, ime roditelja, prezime	MSc Luka, Vladimir, Filipović		
Fakultet	Elektrotehnički fakultet Podgorica		
Studijski program	Doktorske studije elektrotehnike		
Broj indeksa	1/2011		
NAZIV DOKTORSKE DISERTACIJE			
Na službenom jeziku	Kombinovani adaptivni algoritam za raspodjelu opterećenja pri paralelizaciji aplikacija		
Na engleskom jeziku	Combined adaptive load balancing algorithm for parallelization of applications		
Naučna oblast	Računarske nauke		
MENTOR/MENTORI			
Prvi mentor	Prof. dr Božo Krstajić	Univerzitet Crne Gore Elektrotehnički fakultet Podgorica Crna Gora	Automatika i računarstvo
KOMISIJA ZA PREGLED I OCJENU DOKTORSKE DISERTACIJE			
Prof. dr Milutin Radonjić		Univerzitet Crne Gore Elektrotehnički fakultet Crna Gora	Računarske nauke
Prof. dr Božo Krstajić		Univerzitet Crne Gore Elektrotehnički fakultet Crna Gora	Automatika i računarstvo
Prof. dr Slavko Gajin		Univerzitet u Beogradu Elektrotehnički fakultet Beograd Srbija	Računarska tehnika i informatika

Datum značajni za ocjenu doktorske disertacije	
Sjednica Senata na kojoj je data saglasnost na ocjenu teme i kandidata	26.03.2015. godine
Dostavljanja doktorske disertacije organizacionoj jedinici i saglasanost mentora	Saglasnost mentora: 08.07.2019. Predaja disertacije: 08.07.2019.
Sjednica Vijeća organizacione jedinice na kojoj je dat prijedlog za imenovanje komisija za pregled i ocjenu	11.07.2019. godine

doktorske disertacije	

ISPUNJENOST USLOVA DOKTORANDA

U skladu sa članom 38 pravila doktorskih studija kandidat **je/nije** cjelokupna ili dio sopstvenih istraživanja vezanih za doktorsku disertaciju publikovao u časopisu sa **(SCI/SCIE)/(SSCI/A&HCI)** liste kao prvi autor.

Spisak radova doktoranda iz oblasti doktorskih studija koje je publikovao u časopisima sa (upisati odgovarajuću listu)

Radovi u časopisima sa SCI/SCIE liste:

[1] L. Filipović and B. Krstajić, "Combined Load Balancing Algorithm in Distributed Computing Environment", ISSN 1392–124X (print), INFORMATION TECHNOLOGY AND CONTROL, 2016,T.45, Nr.3, DOI: 10.5755/j01.itc.45.3.13084

[2] L. Filipović, D. Mrdak and B. Krstajic, „Performance evaluation of parallel DNA multigene sequence analysis ", Comptes rendus de l'Académie bulgare des sciences, Vol 69, No. 4, 2016. pp.489-496. Print ISSN 1310-1331, Online ISSN 2367-5535.

OSTALI RADOVI VEZANI ZA REZULTATE ISTRAŽIVANJA IZ DOKTORSKE DISERTACIJE:

[3] L. Filipović, D. Mrdak and B. Krstajić, „Performance Evaluation of Computational Phylogeny Software in Parallel Computing Environment ", ICT Innovations 2012 Advances in Intelligent Systems and Computing, volume 207, pp 255-264, DOI: 10.1007/978-3-642-37169-1_25, (ISSBN 978-3-642-37168-4, online ISSBN 978-3-642-37169-1), 2013., Springer.

[4] L. Filipović, B. Krstajić, "Modified master-slave algorithm for load balancing in parallel applications", Journal of Electrical engineering, ISSN 0353-8653, pages 74-83, 2014

[5] L. Filipović, D. Mrdak, B. Krstajić, „DNA muligene approach on HPC using RAxML software", HP-SEE User Forum, Beograd, 2012.

[6] L. Filipović, B. Krstajić, „Predlog poboljšanja master-slave algoritma za raspodjelu opterećenja u MPI paralelnim aplikacijama", Informacione tehnologije - IT 2014, 2014. Zbornik radova, ISBN:978-86-85775-15-4, str. 29 – 32, (http://www.it.ac.me/zbornici/ZbornikIT14.pdf).

[7] L. Filipović, "Optimizacija simulatora CQ komutatora paketa metodom paralelnog programiranja", Informacione tehnologije - IT 2012, 2012.

[8] D. Žujović, L. Filipović, B. Krstajić, "Komparacija performansi sekvencijalnih i paralelnih programa na numerički zahtjevnom primjeru", Informacione tehnologije - IT 2010, 2010.

Obrazloženje mentora o korišćenju doktorske disertacije u publikovanim radovima

Radovi iz okvira doktorske disertacije, u kojima je doktorand MSc Luka Filipović prikazao dobar dio ostvarenih rezultata, objavljeni su u: dva međunarodna časopisa sa SCI/SCI-exp liste (2 rada), jednom međunarodnom časopisu koji nije na listi (1 rad), jednom domaćem časopisu (1 rad) i prezentovani na međunarodnim (1 rad) i domaćim (3 rada) konferencijama. Svi navedeni radovi su pratili rezultate istraživanje kolege Filipovića i odnose se na analizu izbora algoritama za raspodjelu opterećenja paralelizovanih aplikacija u distribuiranom računarskom sistemu.

Posebno se izdvajaju 3 rada, od kojih je jedan publikovan u časopisu sa SCI liste, u kojima su predstavljeni ključni rezultati i ideja sprovedenih istraživanja ([1], [4] i [6]).

U radu "Predlog poboljšanja master-slave algoritma za raspodjelu opterećenja u MPI paralelnim aplikacijama", prezentovanom na konferenciji Informacione tehnologije - IT 2014, i objavljenom u zborniku (ISBN:978-86-85775-15-4, str. 29–32), prezentovana je ideja modifikacije najkorišćenijeg dinamičkog algoritma za raspodjelu opterećenja distribuiranog računarskog sistema (*master-slave* algoritam) i prezentovani rezultati primjene prezentovane modifikacije na paralelizovanoj aplikaciji pomoću MPI metode paralelizacije. Prezentovani rezulatati modifikovanog algoritma su upoređeni sa rezultatima polaznog algoritma i potvrđeno je poboljšanje u smislu smanjenja vremena izvršavanja paralelizovanih MPI aplikacija i povećava stepen iskorištenja distribiuranih računarskih resursa.
Generalizacija ideje modifikovanog *master–slave* algoritma, proširenje njegove primjene i rezultati izvršavanja paralelnih aplikacija su prezentovani u radu "Modified master-slave algorithm for load balancing in parallel applications" koji je publikovan u časopisu Journal of Electrical engineering (ISSN 0353-8653, pages 74-83, 2014.). U ovom radu je prikazani rezultati primjene modifikacije master-slave algoritma koju čini kombinacija statičkog (*domain-decomposition*) i dinamičkog *(master-slave*) algoritma raspodjele opterećenja. No, predloženi algoritam daje dobre rezultate isključivo u homogenom distribuiranom računarskom okruženju pa je kolega nastavio sa istraživanjem i modifikacijom algoritma.
Originalni kombinovani adaptivni algoritam za raspodjelu opterećenja pri paralelizaciji aplikacija je predložen i objavljen u radu pod nazivom "Combined Load Balancing Algorithm in Distributed Computing Environment" koji je publikovan u časopisu INFORMATION TECHNOLOGY AND CONTROL (ISSN 1392–124X (print), 2016, T.45, Nr.3, DOI: 10.5755/j01.itc.45.3.13084, Impact factor 0.707) i gdje je potvrđene prednosti novog algoritma u odnosu na polazne algoritme raspodjele opterećenja. Rezultati istraživanja prezentovani u radu potvrđuju prednosti predloženog rješenja: poboljšana efikasnost paralelne aplikacije i iskoristivost klastera u odnosu na osnovne algoritme, prilagodljivost algoritma stanju resursa i stepenu izvršenja aplikacije primjenom adaptivne strategije određivanja adekvatnije metode raspodjele procesa, primjenljivost predloženog adaptivnog dijela algoritma odlučivanja u bilo kom load balancing algoritmu i širina primjene novog algoritma za sve paralelne aplikacije koje se sastoje od više nezavisnih zadataka.

Datum i ovjera (pečat i potpis odgovorne osobe)

U Podgorici,
18.07.2019. godine

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MP
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Elektrotehnički fakultet

DEKAN

Prilog dokumenta sadrži:

1. Potvrdu o predaji doktorske disertacije organizacionoj jedinici
2. Odluku o imenovanju komisije za pregled i ocjenu doktorske disertacije
3. Kopiju rada publikovanog u časopisu sa odgovarajuće liste
4. Biografiju i bibliografiju kandidata

5. Biografiju i bibliografiju članova komisije za pregled i ocjenu doktorske disertacije sa potvrdom o izboru u odgovarajuće akademsko zvanje i potvrdom da barem jedan član komisije nije u radnom odnosu na Univerzitetu Crne Gore

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Broj: 02/1-1175
Datum: 11.07.2019

Na osnovu službene evidencije i dokumentacije Elektrotehničkog fakulteta u Podgorici, izdaje se

P O T V R D A

MSc Luka Filipović, student doktorskih studija na Elektrotehničkom fakultetu u Podgorici, dana 08.07.2019. godine dostavio je ovom Fakultetu doktorsku disertaciju pod nazivom: „Kombinovani adaptivni algoritam za raspodjelu opterećenja pri paralelizaciji aplikacija“, na dalji postupak.

D E K A N,
Prof. dr Zoran Veljović

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Broj: 02/1-1179
Datum: 11.07.2019

Na osnovu člana 64 Statuta Univerziteta Crne Gore, u vezi sa članom 55 Pravila doktorskih studija, na predlog Komisije za doktorske studije, Vijeće Elektrotehničkog fakulteta u Podgorici, na sjednici od 11.07.2019. godine, donijelo je

O D L U K U

I Utvrđuje se da su ispunjeni uslovi iz Pravila doktorskih studija za dalji rad na doktorskoj disertaciji **„Kombinovani adaptivni algoritam za raspodjelu opterećenja pri paralelizaciji aplikacija“**, kandidata MSc **Luke Filipovića.**

II Predlaže se Komisija za ocjenu navedene doktorske disertacije, u sastavu:

1. Dr Milutin Radonjić, vanredni profesor Elektrotehničkog fakulteta Univerziteta Crne Gore,
2. Dr Božo Krstajić, redovni profesor Elektrotehničkog fakulteta Univerziteta Crne Gore,
3. Dr Slavko Gajin, vanredni profesor Elektrotehničkog fakulteta Univerziteta u Beogradu.

Komisija iz tačke II ove Odluke podnijeće Izvještaj Vijeću Fakulteta u roku od 45 dana od dana imenovanja.

-VIJEĆE ELEKTROTEHNIČKOG FAKULTETA-

D E K A N,
Prof. dr Zoran Veljović

Dostavljeno:
- Senatu,
- Centru za doktorske studije,
- u dosije,
- a/a.

SPISAK RADOVA SA REZULTATIMA IZ DOKTORSKE DISERTACIJE

Međunarodni naučni časopisi (SCI, SCI-exp, lista):

1. **L. Filipović** and B. Krstajić, "Combined Load Balancing Algorithm in Distributed Computing Environment", ISSN 1392–124X (print), INFORMATION TECHNOLOGY AND CONTROL, 2016,T.45, Nr.3, DOI: 10.5755/j01.itc.45.3.13084
2. **L. Filipović**, D. Mrdak and B. Krstajic, „Performance evaluation of parallel DNA multigene sequence analysis", Comptes rendus de l'Académie bulgare des sciences, Vol 69, No. 4, 2016. pp.489-496. Print ISSN 1310-1331, Online ISSN 2367-5535.

Domaći časopisi

1. **L. Filipović**, B. Krstajić, "Modified master-slave algorithm for load balancing in parallel applications", Journal of Electrical engineering, ISSN 0353-8653, pages 74-83, 2014

Domaće konferencije

1. **L. Filipović**, B. Krstajić, „Predlog poboljšanja master-slave algoritma za raspodjelu opterećenja u MPI paralelnim aplikacijama", Informacione tehnologije - IT 2014, 2014.
2. **L. Filipović**, "Optimizacija simulatora CQ komutatora paketa metodom paralelnog programiranja", Informacione tehnologije - IT 2012, 2012.

ISSN 1392–124X (print), ISSN 2335–884X (online) INFORMATION TECHNOLOGY AND CONTROL, 2016, T. 45, Nr. 3

Combined Load Balancing Algorithm in Distributed Computing Environment

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Abstract. Load balancing algorithms and task scheduling are one of the most important tasks in parallel application design and implementation. Proper task assignment to processor cores can minimize execution time and increase the performance of a parallel application. In this paper, we propose a combined load balancing algorithm based on a mixture of well-known domain decomposition and master-slave algorithms. The proposed algorithm minimizes load imbalance and communication between independent tasks. The proposed algorithm improved parallel efficiency using task rescheduling, which had been confirmed with simulation results.

Keywords: Load balancing algorithms; Process scheduling; Parallel programming; Resource utilization.

1. Introduction

Many multidisciplinary scientific fields, such as bioinformatics, biochemistry, electrical engineering and physics, use scientific computing and distributed computing resources for simulations of experiments. Distributed computing clusters consist of closely interconnected servers with multi core processors [1]. The primary focus of many researches in the area of distributed computer scheduling is finding a way to distribute tasks among the CPU cores in order to achieve better performance, such as minimizing job execution time, minimizing communication and maximizing resource utilization. In order to determine this, proper assignment of the tasks to the processor and monitoring of their execution is crucial. Achieving parallelism by redistributing the workload of parallel application segments as computation progresses is referred to as load balancing [2].

The main goal of load balancing algorithms is to find an optimal schedule for the tasks which defines a starting time and an execution resource for each task in order to minimize overall computational time [3]. Execution time of parallel program is the time elapsed between the start of the first task and the completion of the slowest process or process on slowest core. Performance optimization of parallel applications can be done using load balancing algorithms by managing tasks execution during application runtime [4].

The theory of the design of load balancing algorithms started more than forty years ago [5]. Load balancing techniques in parallel systems were developed in two ways: job scheduling on infrastructure and task scheduling inside parallel applications. Various scheduling techniques were developed for high performance and grid clusters [6] [7] and for Cloud infrastructure [8] [9], to achieve maximum utilization of resources, optimize application or virtual machine execution, minimizing timespan between jobs. Similar load balancing algorithms were implemented for scheduling into parallel applications. A certain part of the developed algorithms was developed as general purpose algorithms which are using various application and infrastructure load parameters [10]. On the other side, there are a number of load balancing algorithms created only for scheduling inside specific applications.

Algorithms should be accurate, efficient, stable, portable, and maintainable [11]. Efficient parallel algorithm must avoid communication overheads and load imbalance. Load imbalance of parallel application can occur due to uneven load of computing cores which affect low utilization of distributed system [12]. Many load balancing algorithms have been developed in an effort to coordinate execution time on each core separately, reduce computation time and load imbalance. An efficient load balancing algorithm can improve application performance and help avoid unnecessary delays [3]. In a real distributed environment, a workload of resources varies and it's not always possible to get the resources that are completely free or equally burdened. In addition, many modern supercomputer architectures (such as multi-core or SMP clusters) that look homogeneous from the outside actually conceal a heterogeneous and dynamic environment on the inside. For instance, processors located within the same node are actually competing for shared resources, and intra-node communication is typically much faster than inter-node communication [13]. Losses during execution of parallel applications can happen in imbalanced applications as a result of CPU cores idle time once they have finished their work and wait for slowest core or group of core to finish the given tasks. This phenomenon occurs on heterogeneous clusters or dynamic clusters with a variable load (clusters on which multiple users simultaneously execute parallel applications and thus burden the resources) [11] [14] [15].

Load balancing algorithms can be classified as static and dynamic. Static load balancing algorithms have good usability on homogeneous clusters while they execute tasks on all cores which have similar duration. Performance of programs using these algorithms is reduced at the end of the runtime without possibility of rescheduling. One of widely used static algorithms is domain decomposition algorithm. On the other side, dynamic algorithms can give better efficiency on heterogeneous resources, but make unnecessary communication during executing time. The master slave algorithm is a typical representative of dynamic algorithms [16] [17] [18].

In this paper, we analyze domain decomposition and master slave algorithms, their strengths and weaknesses. We create a new load balancing algorithm by combining these two in order to minimize useless communication between tasks and idle time. The proposed algorithm improves parallel efficiency using task rescheduling, which has been verified through numerical demanding simulation.

The paper is organized as follows. A brief description of the Domain distribution and Master slave load balancing algorithms is given in Section 2. In Section 3, the proposed algorithm is presented. Finally, the simulation results and concluding remarks are given in Sections 4 and 5.

2. Domain distribution and Master-slave load balancing algorithms

Scheduling of parallel tasks using domain decomposition and master slave can be used on a various type of distributed computer resources: homogenous clusters and heterogeneous clusters. Depending on the type of allocated resources, scheduling algorithms can give different efficiency results.

In static load balancing, the assignment of tasks to processors is performed before program execution begins. Scheduled task is always executed on the assigned CPU core. Static scheduling methods minimize the overall execution time of a concurrent program and minimize the communication delays. The advantage of static scheduling methods is that all the overhead of the scheduling process is incurred at compile time, resulting in a more efficient execution time environment compared to dynamic scheduling methods [16] [19] [20].

Domain decomposition (DD) algorithm [17] is one of the most used static algorithms. Many applications in physics, chemistry, mechanics and climate modeling simulations are parallelized using domain decomposition algorithm. With this scheduling policy, tasks are dispatched to all CPU cores with equal probability, according to pre-defined rules or random order. Effieiency of the algorithm is maximal till moment when first cores finishes assigned jobs in T_{min} (Figure 1). From this moment, the fastest core or group of cores are in the idle state, which induces load imbalance and utilization losses, until T_{max} moment when parallel application finishes its work. Load imbalance happens because duration of tasks is not known in advance as well as the impact of external factors which may disrupt performance, which is the main disadvantage of this algorithm. Efficiency of applications using domain distribution algorithm is strongly affected by heterogeneity and variability of distributed computer system. Domain distribution algorithm is the most efficient when the computational problem can be divided into equal parts and computational load is equally distributed among the processor cores [13].

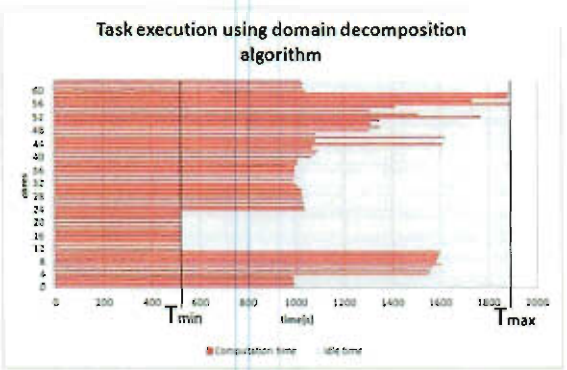

Figure 1. Distribution of the tasks using domain decomposition algorithm

Dynamic load balancing is based on the rescheduling of processes among the CPU cores during execution time of parallel program. Rescheduling is performed by transferring tasks from the heavily loaded processors to the lightly loaded cores with the aim of reducing the execution time and minimizing load imbalance. The load balancing operations may be managed by a single core or distributed among all the processing elements that participate in the load balancing process. Each core passes its current load information to its neighbors at the specified time intervals, resulting the redistribution of load among all the processing elements in a short period of time [21]. Main advantages of dynamic algorithms is a fact that system doesn't need to be aware of the tasks run-time bebavior before execution and adjustment of task scheduling to the resources. Disadvantage of dynamic algorithms is run-time overhead for transferring load information among processors, decision making for the processes redistribution and communication delays for task relocation [22].

Master-slave (MS) paradigm [18], as one of the basic and the most used dynamic scheduling algorithms, is often used in computational biology parallel simulations [23] [24]. It involves two types of computing cores. Preprocessing, task alloeation and post processing is performed on the master core, while task execution is performed on slave cores. Master core generates a list of tasks that need to he executed and sends one or more instructions to slave cores. Slave core, upon completion of given tasks, signals the end of assigned tasks whereupon master core allocates them the next task or list of tasks. This routine is repeated until all processes are finished. The advantage of the algorithm is reflected in a good management process. One disadvantage of an algorithm is an increased communication between the master and slave cores and potential waiting of slave cores for allocation of new tasks waiting for execution. Tasks cannot be executed on master core, so this is another disadvantage, especially during the execution on the smaller number of cores [25].

3. Proposed combined algorithm (CA)

In this section, a new load balancing algorithm, based on combination of DD and MS algorithms, is presented. The motivation was to improve load balancing performance and execution time for parallel applications which consist of many independent tasks. The proposed combined algorithm consists of three phases.

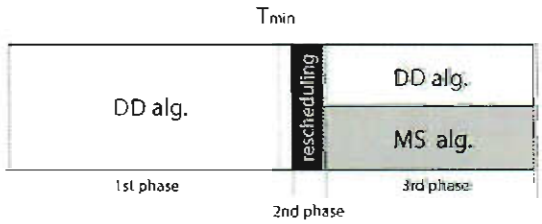

Figure 2. The proposed algorithm

Phase 1. As seen in Figure 1, application's usability with DD algorithm is 100% till T_{min} moment. Opposed to this algorithm, master-slave makes load imbalance from the start of applieation because tasks can't be executed on master core. Therefore, DD algorithm is used in the first phase of the proposed CA algorithm (Figure 2). In the first phase CA works as DD until T_{min} when all assigned tasks to the fastest core are finished. The fastest eore then sends signal to each other core to finish task which it executes and terminate execution of rest assigned unfinished tasks. This phase is finished when all cores finish exeeuting started tasks.

Phase 2. In the second phase, all computing cores send reports to the pre-specified core. Each report includes:

1. status of assigned tasks,
2. execution time of finished tasks,
3. information about resources (core speed and allocated memory).

Pre-specified eore analyzes received information, makes a list of unfinished tasks, chooses algorithm (DD or MS) for the third phase, and performs rescheduling. The choice of the algorithm is performed according to the number of computing cores, heterogeneity of a cluster (c) and execution time of each performed task (b).

Domain decomposition algorithm is chosen for the third phase if:

DD1) application runs on homogeneous cluster on less than 32 cores,

DD2) each core from the first phase executes similar number of tasks with similar duration,

DD3) number of unfinished tasks is less or equal to the number of cores where parallel application executes.

Master–slave algorithm is chosen for the third phase if:

MS1) application runs on more than 32 cores, i.e. when master-slave algorithm can't produce a significant loss of utilization due execution.

MS2) application runs on heterogeneous cluster or on clusters where load rapidly changes,

MS3) duration of tasks is significantly different,

MS4) each core from the first phase executed significantly different number of tasks.

Rescheduling algorithm makes a list of unfinished tasks in accordance with selected algorithm. If DD algorithm is selected, each core receives a list of unfinished tasks for execution. The number of assigned tasks to each core is calculated according to the number of tasks finished in the first phase on each core separately. If MS algorithm is selected, then the master core receives a list of all unfinished tasks which will be assigned to the slave nodes for execution in the third phase.

Phase 3. Selected algorithm from the second phase is executed in the third phase of the proposed algorithm.

Figure 3 presents operations of combined algorithm per stages. In the first phase of the proposed algorithm, the DD algorithm was used (marked with blue). The second phase selected MS algorithm because parallel application was started on 64 cores (according MS1 rule) and nearly half of tasks were unfinished after termination (according MS4 rule) and made rescheduling (marked with red). Regarding decision from the second phase in this example, MS was executed in the third phase (marked with green).

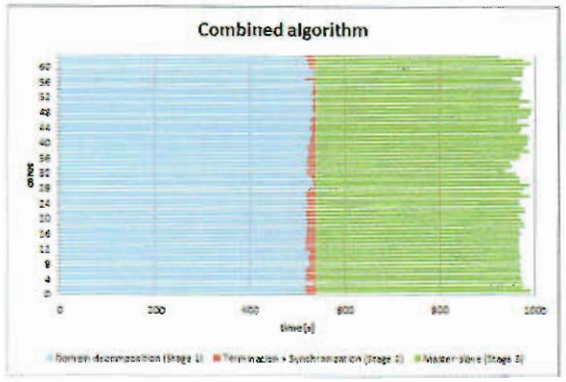

Figure 3. Task scheduling using combined algorithm

According to analysis and rescheduling in the second phase, the proposed algorithm increases the efficiency and reduces execution time for parallel applications in the third phase. The execution time of the proposed algorithm is shorter (Figure 3) than execution time of the standard DD algorithm measured in same conditions (Figure 1). Moreover, the efficiency of the proposed algorithm is increased due to minimized idle time and improved resource usage.

Disadvantages of the combined algorithm are termination of assigned tasks at the end of the first phase and duration of the second phase. Duration of the second phase is insignificantly low and can't affect the efficiency of parallel application. Termination of assigned tasks in the first phase can increase duration of this phase only if there is one task whose duration is enormously higher than duration of others. This increase of first phase duration can affect the performance of the whole algorithm. In that case, there is no improvement in efficiency compared with DD and MS.

The combined algorithm works as DD algorithm during their maximal efficiency and interrupts work when its effectiveness starts to weaken. It has a similar performance as DD in the case when DD has a high efficiency. The proposed algorithm has better performance than DD when DD has low efficiency due to interruption and rescheduling.

CA has better performance than MS because MS doesn't execute tasks on master core whole time and has less communication loses during execution time. The MS algorithm produce less efficiency than the proposed algorithm which starts as DD and makes rescheduling to achieve better resource usage.

4. The results of simulation and analysis

Performance of the combined algorithm is verified through numerical demanding application Cross-Point queued switch (CQ) simulator for performance analysis [26]. Simulator is parallelized using MPI [27]. It executes simulations of eight different switching algorithms (LQF, RR, ERR, FBRR, EELQF, ELQF, FBLQF and RAND) with 12 different buffer sizes on 32 input files of generated traffic. Simulation was performed for matrix of 16x16 and 1.000.000 time slots. During the preprocessing, simulator prepares 3072 independent tasks. Simulation was performed on Paradox [28] HPC cluster during HP-SEE project [29].

Figure 4 presents frequency of computational time of CQ tasks. 95% of tasks finished assigned work between 12 and 18 seconds. The average execution time was 15.10 seconds, while the longest task was executed in 165 seconds. The statistics is based on the pattern of 800.000 executed tasks.

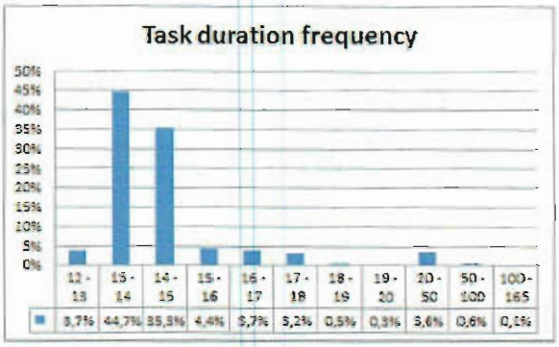

Figure 4. Frequency of task computational time

Total execution time depends on the duration of each task and their scheduling. Simulations using DD, MS and CA are performed on 16-128 cores. Input files were copied on nodes in the preprocessing phase of the application. Average results of twenty executions at different clusters loads are presented at Figure 5.

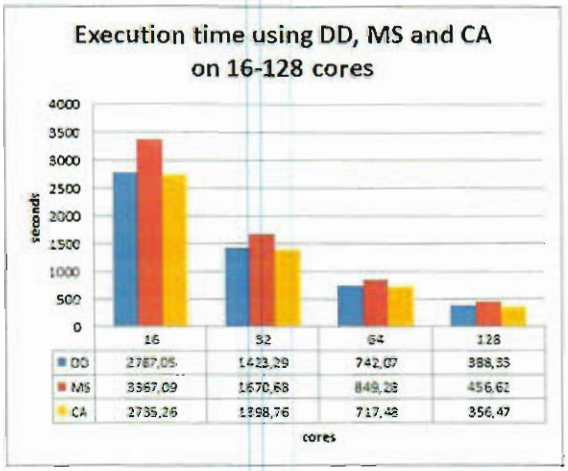

Figure 5. Average execution time using three scheduling algorithms on 16-128 cores

CA gave better results than DD and MS algorithms in all conditions. The impact of rescheduling and reduced runtime was more noticeable as the number of cores increased. In few cases, CA required up to 0.5% time more than DD. In the best case, CA finished execution 21.6% faster than DD due task rescheduling at the end of application. MS algorithm required more time than DD and CA, especially during execution on 16 cores due to described disadvantages.

Figure 6 presents execution time comparison between CA and other algorithms. The difference between CA and DD ranges from 1.7% to 8.2%. DD required more time to execute than CA due to static scheduling process. The difference between CA and DD was higher when the application was started on larger number of cores.

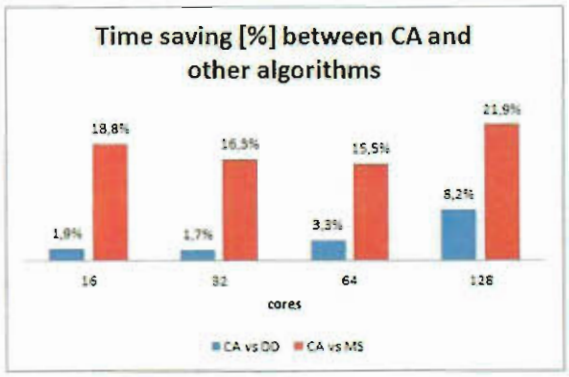

Figure 6. Execution time comparison between CA, DD and MS

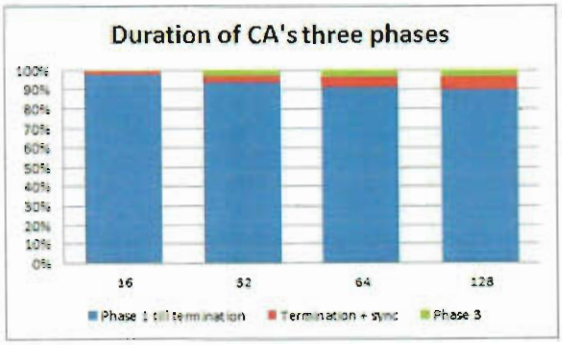

Figure 7. Time distribution of CA's phases

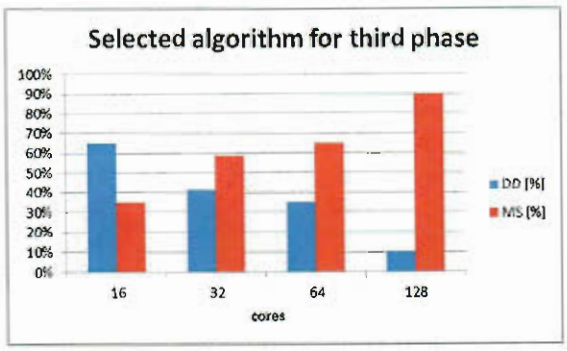

Figure 8. Algorithm choice in CA's third phase

The difference between CA and MS was bigger, since MS algorithm had specified weaknesses. Inability to execute tasks on master core produced losses during execution on lower cores. Communication between cores during the entire process of execution caused lower efficiency on 128 cores.

Figure 7 presents time distribution of CA phases. Three segments are indicated: the first phase till termination, termination and synchronization phase and the third phase for simulations performed on 16-128 cores. Duration of termination and third phase increased as simulation was performed on bigger number of cores. Termination phase time, marked by red color, increased on 128 cores because the fastest core waited for more cores to finish tasks which were executed in time when termination signal was sent. We noticed high efficiency of CA and DD algorithm on 16 cores and higher number of tasks which were rescheduled on 64-128 cores.

Figure 8 shows which algorithm performed scheduling in the third phase. Domain distribution was selected in the most cases when simulation was executed on 16 cores, because the program detected Paradox as a homogenous cluster with a number of allowed cores less than 32. On the other hand, master-slave had priority in other cases because the algorithm from the second phase detected tasks with different duration and selected this dynamic algorithm for the third phase.

5. Conclusion

In this paper, the combined load balancing algorithm for parallel applications which consist of many independent tasks has been presented. The algorithm is created on the strengths of the domain decomposition and master slave algorithms and task rescheduling. Using mixture of these, standard static and dynamic, algorithms we reduced execution time, minimized load imbalance and improved performance of parallel application in various distributed environments. This paper also identifies situations when the proposed algorithm doesn't provide improvements, but it still maintains performance comparable to constituent algorithms.

The main contribution of this paper can be summarized as follows:

- the combined load balancing algorithm based on domain decomposition and master slave algorithms has been proposed,
- heuristic approach for the selection of load balancing algorithm after domain decomposition in the first phase,
- new algorithm improves the performance of parallel application which consist of many independent tasks,
- simulation results which confirmed better performance of the combined algorithm when compared with domain decomposition and master slave algorithms.

Further research will be focused on evaluation of the combined algorithm on various heterogeneous clusters as well as its implementation for practical parallel applications.

Acknowledgments

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Automatique et informatique

PERFORMANCE EVALUATION OF PARALLEL DNA MULTIGENE SEQUENCE ANALYSIS

Luka Filipović, Danilo Mrdak*, Božo Krstajić**

(*Submitted by Corresponding Member S. Hadjitodorov on October 30, 2014*)

Abstract

Computational phylogeny and DNA sequence analysis are challenging even for the most powerful supercomputers. RAxML is the fastest and the most accurate software in the area of phylogenetic analysis, mostly used for sequential and parallel maximum likelihood based inference of large phylogenetic trees. In this paper we present scalability analysis of multigene DNA sequence analysis using RAxML on the high performance cluster. We analyzed five different genes, two real and additional three designed genes, in order to test reliability of the constructed census phylogeny tree. We have proved validity of parallelism using MPI for analyzed dataset with the best efficiency results during execution on up to 32 cores.

Key words: parallel and distributed computing, performance analysis, computational efficiency, DNA computing, bioinformatics

1. Introduction. In the last few decades, we have witnessed the increasing popularity of distributed systems and computer science, in general. Distributed

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computing covers many of the activities occurring in the computer and communications world and allows sharing of available computer resources and peripherals. The concept itself was developed as a response to the constant need to increase performance, lower prices, and long-term productivity [1, 2]. Parallel computing enables division of larger problems into smaller ones and solving them simultaneously on distributed systems [3]. It is often used in Bioinformatics, especially in computational intensive applications of DNA (*Deoxyribonucleic acid*) sequence analysis.

One of the significant applications in the area of DNA sequence analysis is RAxML (Random Axelerated Maximum Likelihood), the program for sequential and parallel Maximum Likelihood based inference of large phylogenetic trees [4, 5]. Using RAxML, we analyzed five different DNA datasets of different trout species and scalability of multigene DNA sequence analysis on PARADOX [6] cluster with up to 64 cores. We measured the performance of RAxML followed by analysis of execution time, speedup and efficiency.

2. The RAxML software. The RAxML has been developed to perform phylogenetic analysis using the maximum likelihood optimality criterion [4, 7]. Software allows computationally efficient and biologically accurate analysis data sets of any size. RAxML can use a variety of different character sets, including nucleotide, amino acid, binary, and multi-state character state data [4, 7, 8]. It has a sequential and parallel version. It is parallelized in various ways and suitable for any type of multicore cluster. Parallel versions can be divided into coarse grained, fine grained and hybrid [9].

Coarse grained parallelization uses MPI (Message Passing Interface) [10], the most commonly used paradigm in writing parallel programs. It requires minimal communication between cluster nodes, which makes fast and expensive interconnection between cluster nodes obsolete. RAxML's MPI parallelization is performed over the number of randomly generated tree searches, whereby an equal number of generated trees is assigned to each computing core for analysis [9].

Fine grained parallelism uses Pthreads for shared memory parallelism [11]. It is suitable for datasets with long DNA sequences which can be divided per cores during analysis. The main disadvantage of fine grained parallelism, which is limited by a sharing memory paradigm, is that it can only run on a single node.

Hybrid version combines coarse and fine grained parallelization and overcomes limitations of the fine grained parallelization while executing more shared memory processes on different nodes [9, 12]. Communication inside a single node uses Pthreads while between different nodes it is based on MPI. It has yielded the best results for large datasets with lengthy DNA sequences [13].

3. Analyzed DNA datasets. Fast development of molecular techniques caused a huge increase of available DNA data sets published in Gene Bank worldwide [14]. DNA data sets represent decoded DNA segments of different organisms and their different genes and DNA sectors. In spite of DNA sequence type they

all contain part of phylogenetic information which we used in our attempts of reconstruction of ancestor-descendant relationships among theme we named as phylogeny. However, it is a common situation when phylogeny has been reconstructed on different genes or on different parts of structural DNA that we got different phylogeny patterns among the same sets of individual species or sets of phylogeny lineages from different geographical regions within one species. Therefore, we start with a multi-gene approach using several genes or structural DNA parts while we have obtained a census tree that represents the most probable phylogeny reconstruction as the analysis outcome. The more genes or DNA structural segment we use, the more the consensus phylogeny tree gets closer to a real event of evolutionary history within the analyzed group.

In our analysis, we used 5 different DNA data sets for the same species and lineages. Original DNA sequences are taken from mitochondrial DNA, structural part called d-loop, and mitochondrial gene Cytochrome b. Other three genes represent a modification of two real genes. We analyzed Mediterranean, Adriatic, Danubian and Atlantic linage of brown trout (*Salmo cf. trutta*), marble (*Salmo marmoratus*), soft-muzzled (*Salmo salmothymus*), Ohrid lake trout (*Salmo acantholingua*), atlantic salmon (*Salmo salar*), river huchen (*Hucho hucho*) and grayling (*Thymallus thymallus*). Real gene sequences of different species and lineages were downloaded from The National Center for Biotechnology Information [14] database. Gene 3 and gene 4 represent a slightly modified d-loop and Cytochrome b, respectively. During the construction of these two genes we paid attention whether the phylogeny information was persevered as in original genes. We constructed a so-called "fake gene" as gene 5 that has completely different phylogenetic information.

We performed simulations on specified genes:

- Multigene analysis of two real sequences, labelled as G-12
- Multigene analysis of two real genes and two slightly modified ones, labelled as G-1234
- Multigene analysis of two real sequences and "fake gene", labelled as G-125
- Multigene analysis of all 5 genes, two real, two slightly modified and a "fake gene", labelled as G-12345

As results of analysis and reconstruction of phylogeny we got the consensus phylogeny tree based on 3025 base pairs divided into 5 genes. We also analyzed how different genes that carry different phylogeny information affect the census tree.

4. Scalability results of RAxML parallelization. The subject of our research was the efficiency of parallel reconstruction of phylogenetic trees based on multigene DNA dataset using RAxML software. RAxML supports MPI, Pthreads and hybrid parallelization combining shared and distributed memory approach. The appropriate RAxML parallelization method should be determined in accordance with dataset size and type of the available cluster. MPI is, in general, suit-

able for RAxML parallelization in the analysis of many different DNA sequences, while hybrid method can give better results provided that DNA sequence is long enough to be divided and analyzed on multiple cores. All of the specified parallelization methods were analyzed for a single gene with 123 DNA sequences of *Salmo cf. trutta* with 552 base pairs per DNA sequence whereas RAxML's MPI parallelization has yielded the best performance [15]. In our research, real genes (gene 1 and 2) had similar length as genes in a single gene analysis. Therefore, we decided to focus on using MPI parallelization in our scalability analysis.

In order to measure the performance of parallel application, we used three main indicators: execution time, speedup and efficiency [16]. Less important factors which can help in performance measurement and making choices about parallelism are a number of processor used during execution, the size of the data being processed and inter-processor communications [17].

Scalability testing was performed on four gene combinations specified in Chapter 3 as a serial and parallel application using up to 64 cores. Analyses were performed with 1000 bootstraps. In real distributed environment, workload of resources varied. We made up to 10 time measurements for each analysis and presented mean results. The execution time, speedup and efficiency of parallel code are graphically presented in Fig. 1–3.

Figure 1 shows that execution time drastically drops with the increase of number of cores. The duration of the simulations was gradually decreased as the number of cores was increased. Serial job and parallel jobs on up to 8 cores were executed on a single server. They all showed almost linear speedup (Fig. 2) and efficiency of more than 85%. Simulations on more servers (8–64 cores) showed drastic reduction of speedup and efficiency. This fact indicates that the communication between servers still has plenty of influence on weakening of RAxML MPI parallelization. The worst speedup is noticeable for G-12 simulation (Fig. 2), which has the least number of operations, wherein speedup over 15 and time be-

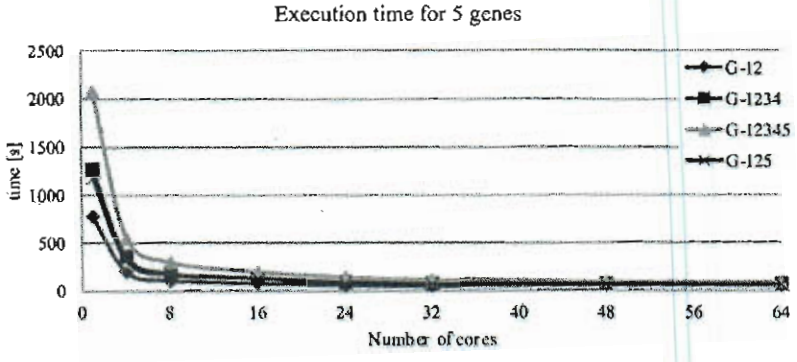

Fig. 1. RAxML multigene analysis execution times

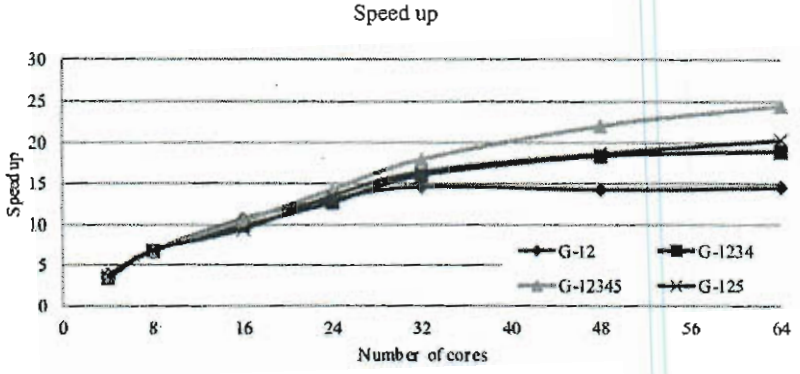

Fig. 2. Speedup of RAxML parallel code

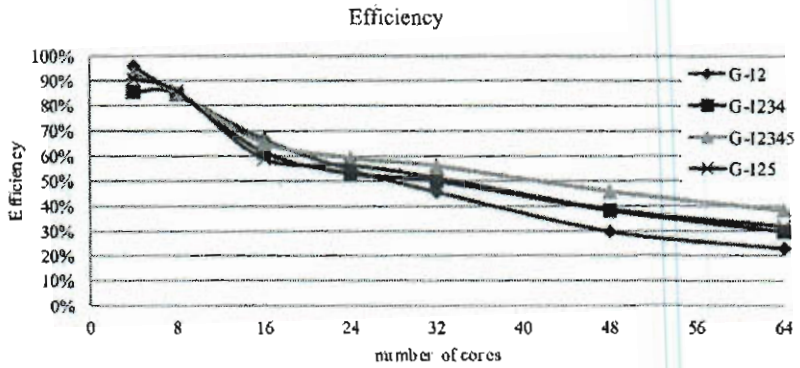

Fig. 3. Efficiency of RAxML parallel code

low 53 seconds were not reached. We believe that the short time of each analysis and time gap between analyses when servers communicate between themselves were a cause of stagnation. Other simulations had almost linear speedup over 16 cores, but not as noticeable as in the execution on a single server. The best speedup and efficiency (Fig. 2, 3) were reached for simulation with the largest number of operations (G-12345).

Parallel efficiency of 50% can be used as a guideline for reasonable choice when deciding on how may cores we need to run an application during production [18]. Efficiency of more than 50% is achieved on 32 or less cores in almost all tests in our analysis. According to that fact, execution on up to 32 cores is optimized for our analysis and analysis with dataset of similar size.

5. Conclusion. In this paper, we analyzed scalability results of multigene DNA sequence analysis (of real and fake genes) and mutual influence of hybrid on real genes using RAxML software on the HPC cluster. In terms of biology, this

analysis showed that the RAxML software keeps phylogeny information during multigene analysis. Although fake gene represents 24.6% of analyzed base pairs (744 of 3025 base pairs), that did not significantly affect the change of phylogeny information in census tree. It shows that RAxML software does not consider a number of base pairs in different genes when forming the census tree, but it gives the same importance to each tree based on an individual gene. Main phylogenetic information (ancestor-decedent relationships) was preserved, whereas we had noticed a slight change in evolution distances among analyzed taxa and lineages. The RAxML software treats each gene in multi-gene analysis as an individual evolutionary unit and not based on the amount of information they carry (number of base pairs in DNA sequence). This is also in concordance with the theory of evolution. We showed that RAxML software attributes the equal significance, in terms of evolution and possible phylogenetic relationships, to each gene in multi-gene approach.

RAxML supports various parallel models and works on different platforms. In our multigene performance test, on the sample described in Chapter 3, MPI has shown the best speedup on less than 32 cores in which the efficiency was higher than 50%. Low efficiency loss (up to 15%) was observed when the same application was running on a single server. Parallel version of RAxML has shown good scalability results when running on a small number of cores, while efficiency decreased with the increase of number of cores. Measurement results showed too large losses during the execution of the application on 64 or more cores. Performance analysis has shown similar speedup and efficiency graphs in case of a single gene and multigene analysis, which vary depending on the number of cores and input DNA sequences. If we compare multigene scalability results from this paper and results from a single gene analysis with small [16], medium and large dataset [9], we can conclude that speedup and efficiency graphs are similar in multigene and single gene analysis. We proved validity of parallelization on up to 32 cores, while parallel analysis on a larger number of cores caused too large waste of resources.

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BIOGRAFIJA

Luka Filipović je rođen 02.02.1981. u Podgorici, Crna Gora. Osnovnu školu „Sutjeska" je završio 1995.godine u Podgorici sa diplomom „Luča". Matematičku gimnaziju „Slobodan Škerović" u Podgorici je završio 1999.god. Osvajač je prvog mjesta u programiranju na republičkom takmičenju za učenike srednjih škola. Elektrotehnički fakultet, odsjek za elektroniku, telekomunikacije i računare se upisao 1999. godine. Diplomirao je decembra 2004. godine odbranivši rad na temu "Aplikacija za statistiku dial-up pristupa IS provajderu". Nakon toga upisao magistarske studije na Elektrotehničkom fakultetu. Odbranom magistarskog rada na temu "Analiza upravljanja distribuiranim računarskim sistemom pomoću portala" završava studije marta 2009 godine. Na Elektrotehničkom fakultetu u Podgorici 2011. godine upisuje doktorske studije, oblast istraživanja računari. Položio je sve ispite predviđene planom i programom i odbranio polazna istraživanja.

Od septembra 2003. godine radi u Centru informacionog sistema Univerziteta Crne Gore, trenutno na mjestu rukovodioca odjeljenja za razvoj i održavanje. Autor je ili dio tima koji je razvio više aplikacija akademske mreže Univerziteta. Učesnik je više naučno-istraživačkih projekata finansiranih od strane Evropske komisije: SEE-GRID-2 (FP6), SEE-GRID-SCI, HP SEE, EGI Inspire, Euraxess (FP7) i VI-SEEM (H2020). Učestvovao je i u više nacionalnih projekata iz oblasti distribuiranih računarskih sistema, informacionih sistema i eLearning-a. U sklopu usavršavanja je pohađao više kurseva iz oblasti distribuiranih računarskih sistema, paralelnog programiranja i data science-a. Dosadašnji naučno-istraživački rad rezultirao je objavljivanjem radova u međunarodnim i domaćim časopisima i prezentacijama na međunarodnim i domaćim naučnim skupovima.

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Biografija - Milutin Radonjić

Prof. dr Milutin Radonjić je rođen 9.07.1966. godine u Beogradu. Osnovnu i srednju školu završio je u Titogradu, stekavši zvanje pomoćnog istraživača u matematici. Kao učenik osnovne škole ostvario je zapažene rezultate na takmičenju iz fizike u okviru pokreta "Nauka mladima". Nosilac je diplome "Luča".

Studije na Elektrotehničkom fakultetu završio je 1991. godine, sa prosječnom ocjenom 9,56. Kao student četvrte godine nagrađen je studentskom nagradom "19. decembar". Za vrijeme studija bio je korisnik stipendije Vlade Republike Crne Gore za talentovane studente. Od februara 1993. godine do danas radi na Elektrotehničkom fakultetu u Podgorici u zvanju asistenta pripravnika, asistenta, docenta i vanrednog profesora.

Postdiplomske studije završio je 1997. godine na ETF-u u Podgorici, na odsjeku za Računare, sa prosječnom ocjenom 10. Doktorsku tezu pod naslovom "Prilog analizi performansi CQ komutatora paketa sa stanovišta veličine i algoritama upravljanja redovima čekanja" odbranio je 19. maja 2011. godine na Elektrotehničkom fakultetu u Podgorici.

U septembru 2012. godine izabran je u zvanje docenta, a u oktobru 2017. godine u zvanje vanrednog profesora na Elektrotehničkom fakultetu Univerziteta Crne Gore.

Oblasti njegovog naučnog interesovanja su: mikroprocesorski sistemi, računarske mreže, projektovanje digitalnih sistema.

Kao autor ili koautor objavio je sedam radova u referentnim međunarodnim časopisima sa SCI/SCIE liste, više radova u regionalnim i domaćim časopisima, više od sedamdeset radova na međunarodnim i regionalnim konferencijama i dva rada po pozivu na naučnim skupovima. Autor je zbirke zadataka u izdanju Univerziteta Crne Gore i koautor dva udžbenika.

Član je IEEE i ACM. Član je i organizacionog i programskog odbora konferencije "Informacione tehnologije", uređivačkog odbora časopisa "ETF Journal of Electrical Engineering" i recenzent u više referentnih međunarodnih časopisa. Član je tehničkog komiteta za informacione tehnologije u Institutu za standardizaciju Crne Gore.

Učestvovao je kao član projektnog tima na po jednom međunarodnom COST i IPA projektu, na dva međunarodna projekta finansirana od strane EU kroz FP7 program, na dva bilateralna projekta, na dva nacionalna projekta i na prvom centru izvrsnosti u Crnoj Gori (BIO-ICT). Ima i višegodišnje uspješno iskustvo u saradnji sa privrednim subjektima na mnogobrojnim projektima.

Za vrijeme rada na međunarodnim projektima imao je kraće studijske boravke na University of Ghent (Belgija) i u kompaniji Erikson Nikola Tesla (Hrvatska).

Od septembra 2013 godine do avgusta 2019 obavlja funkciju prodekana za razvoj i istraživanje na Elektrotehničkom fakultetu Univerziteta Crne Gore.

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O D L U K U
O IZBORU U ZVANJE

Dr Milutin Radonjić bira se u akademsko zvanje **vanredni profesor za oblast Digitalni sistemi i informatika na Elektrotehničkom fakultetu,** na period od pet godina.

Senat Univerziteta Crne Gore
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Stručna biografija – dr Slavko Gajin, docent

1. Biografski podaci

Slavko Gajin je rođen u Zemunu 1968. godine. Nakon završetka srednje škole "Matematička gimnazija" u Beogradu 1997. god. i sticanja diplome Vuk Karadžić, upisao je Elektrotehnički fakultet Univerziteta u Beogradu (ETF), smer Računarska tehnika i informatika, nakon čega je odslužio vojni rok. ETF je završio u roku, 1993. godine, sa prosečnom ocenom 9.12. Na Elektrotehničkom fakulteta Univerziteta u Beogradu je odbranio magistarsku tezu pod nazivom "Analiza adaptivnosti modela zaokreta u čvrstospregnutim multiračunarskim mrežama", a 2007. godine i doktorsku disertaciju pod nazivom "Opšti model determinističkog rutiranja u multiračunarskim mrežama".

Neposredno pred završetak studija zaposlio se u Računarskom centru Univerziteta u Beogradu (RCUB). Krajem maja meseca 1999. god. raspoređen je na mesto zamenika direktora RCUB, a krajem 2010. godine imenovan je na mesto direktora RCUB-a, što i sada obavlja.

Od 2008. godine izabran je u zvanje docenta i angažovan je u nastavi na Elektrotehničkom fakulteta Univerziteta u Beogradu sa 25% radnog vremena na predmetima iz oblasti računarskih mreža na osnovnim, master i doktorskim akademskim studijama. Od 2009. godine angažovan je i kao docent u nastavi na Elektrotehničkom fakultetu u Banjaluci na predmetu Internet tehnologije.

2. Naučno-stručna delatnost

Slavko Gajin je autor poglavlja u knjizi međunarodnog značaja i 36 (14) naučnih radova (u zagradama je broj radova u poslednjem petogodištu) i to: 7 (5) rada u međunarodnim naučnim časopisima sa impakt faktorom, 15 (9) radova prezentovanih i objavljenih u zbornicima radova na međunarodnim naučnim skupovima, 1 (0) rad u domaćim časopisima, 13 (1) radova u zbornicima radova domaćih skupova.

Od 1997. godine učestvovao je na 4 istraživačko-tehnološka projekta Ministarstva prosvete, nauke i tehnološkog razvoja, na kojima je radio najpre kao istraživač, a kasnije i kao rukovodilac tima, kao i učesnik na jednom projektu unapređenja nastave. Od 2002. godine učestovao je na 12 evropskih projekata i to 2 H2020 projekta, 8 FP projekata (FP5, FP6 i FP7), 1 TEMPUS i 1 INTERREG projekat, kao član ili rukovodilac tima.

Od 1995. godine, učestvovao je na velikom broju idejnih i glavnih projekata iz uže naučno-stručne oblasti kojom se bavi – projektovanje računarskih mreža (20 projekata). Svi glavni projekti su realizovani (izvedeni), a na većini projekata je bio odgovorni projektant.

Slavko Gajin je takođe bio rukovodilac ili učesnik ukupno 11 softverskih projekata ETF-a, kao i 4 softverska projekta iz oblasti praćenja rada i upravljanja računarskih mreža, od kojih je 1 proizvod priznat kao industrijsko tehničko rešenje na međunarodnom nivou od strane kompanije Cisco Systems, kroz sertifikovanje interoperabilnosti u okviru programa Cisco Developer Network.

Slavko Gajin je kao rukovodilac projekta dobio plaketu Društva za informatiku Srbije za izvanredan doprinos u razvoju informatike u 2002. godini, za proizvodi NetIS, koji je nastao kao rezultat rada na tehnološkom projektu Ministarstva prosvete, nauke i tehnološkog razvoja.

Slavko Gajin je od 2012. godine predstavnik Republike Srbije u stručnom telu „e-Infrastructure Reflection Group" (e-IRG), koje ima savetodavnu ulogu Evropske komisije u oblasti elektronskih infrastruktura.

Slavko Gajin je autor ili koautor sledećih radova, odnosno rukovodilac ili učesnik sledećih projekata (**sa „(a)" su označeni radovi u poslednjih 5 godina, sa „(b)" su radovi pre toga**):

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9. (a) **Slavko Gajin**, Petar Bojović: "Monitoring, analyzing and cleaning DNS configuration errors across European NRENs", TERENA Networking Conference 2013, Mastricht, Netherlands, 2013, (M32)
10. (b) Mirjana Devetaković, Mila Pucar, **Slavko Gajin**, „A Knowledge Base supporting the Technological Research Project TR36035 on Climate Changes and Urban Development", ICIST 2013 - 3rd International Conference on Information Society Technology and Management, Kopaonik 2013. god., (M34)
11. (b) M Savic, **S Gajin**, M Bozic, "SNMP based Grid infrastructure monitoring system", IEEE MIPRO, 2011 Proceedings of the 34th International Convention, p. 231-235, (M31)
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Projekti tehnološkog razvoja Ministarstva prosvete, nauke i tehnološkog razvoja:

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2. (a) „Prostorni, ekološki, energetski i društveni aspekti razvoja naselja i klimatske promene – međusobni uticaju", evidencioni broj 36035, 2011-2018. god.
3. (b) "Razvoj kompjuterskih metoda i softvera za modeliranje i simulacije u oblasti opšteg i biomedicinskog inženjeringa", 2005-2007. god.
4. (b) "Projekat realizacije integralnog informacionog sistema i monitoringa računarske mreže", evidencioni broj 1-253, 2002.-2004. god.
5. (b) "Opšti elementi i posebne primene zaštite podataka u računarskim sistemima i mrežama", evidencioni broj S.1.02.05.0163, 1997.-2000. god.

Međunarodni projekata:

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3. (a) FP7 GN3plus - "Multi-Gigabit European Research and Education Network and Associated Services", 1.4.2013.-31.3.2015., www.geant.net, zamenik rukovodioca tima
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5. (b) FP7 SEERA-EI – "SouthEast European Research Area - e-Infrastructure", 1.4.2009.-31.3.2012., www.seera-ei.eu, član projektnog tima
6. (b) TEMPUS ViCES - "Video Conferencing Educational Services", 144650-TEMPUS-2008-IT-JPGR, 2009. - 2011. god., vices.marnet.net.mk, rukovodilac tima
7. (b) FP6 SEEREN2 – "South-Eastern European Research & Education Network", oktobar 2006. - april 2008. god., www.seeren.org, rukovodilac tima
8. (b) FP6 SEEFIRE – South-East Europe Fibre Infrastructure for Research and Education", 2005.-2006. god., www.seefire.org, rukovodilac tima
9. (b) FP6 SEEGRID –"South-Eastern European GRID-enabled eInfrastructure Developement", 1.5.2004. - 30.4.2006., www.see-grid.org, član projektnog tima
10. (b) FP6 SEEGRID2 – "South-Eastern European GRID-enabled eInfrastructure Developement 2", 2006-2008. god., www.see-grid.eu, član projektnog tima
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1. (a) Matična evidencija osiguranih lica, RFZO, 2002.–danas
2. (a) Elektronsko fakturisanje lekova i pomagala propisanih na teret sredstava Republičkog zavoda za zdravstveno osiguranje, RFZO, 2002.–danas
3. (a) Elektronska evidencija propisanih i izdatih lekova pod specijalnim režimom izdavanja, RFZO, 2002.–danas
4. (a) Zdravstveni informacioni sistem primarne zdravstvene zaštite, 2005.–danas
5. (a) Podsistem za podršku rada pisarnice Republičkog zavoda za zdravstveno osiguranje, 2009.–danas
6. (a) Razvoj, implementacija i održavanje Opštinskog informacionog sistema – OpIS, 2000.-danas
7. (a) Razvoj, implementacija i održavanje Softverskog sistema za evidenciju matičnih knjiga, 2004.-danas
8. (b) Razvoj, implementacija i održavanje informacionog sistema za obračun i naplatu električne energije, RTV pretplatu i pružanje elektrodistributivnih usluga potrošačima, EDB, 2006.-2103.
9. (b) Razvoj, implementacija i održavanje Informacionog sistem za magacinsko, materijalno i pogonsko knjigovodstvo, Narodna banka Srbije-Zavod za izradu novčanica, 2009-2013.

10. (b) Razvoj, implementacija i održavanje informacionog sistema za praćenje proizvoda NBS-ZIN od posebnog interesa, Narodna banka Srbije-Zavod za izradu novčanica, 2007–2013.
11. (b) Testiranje DNS domena, RNIDS, 2012. god.

Ostali stručni projekti:

1. NetVizura NetFlow Analizer – softverski sistem za analizu mrežnog saobraćaja, 2013-danas
2. NetVizura EvenLog Analizer – softverski sistem za analizu syslog i snmp trap poruka, 2013-danas
3. NetVizura DNS Analizer – softverski sistem za testiranje DNS domena, 2013-danas
4. NetVizura NetFlow Network – softverski sistem za monitoring računarskih mreža, 2015-danas

Predavanja po pozivu ili tutorijali na međunarodnim stručnim skupovima:

1. (b) **Slavko Gajin**, "Monitoring and analyzing audio,video, and multimedia traffic on the network", Campus network monitoring workshop, 24–25. April 2012, Brno, Czech Republic
2. (b) **Slavko Gajin**, "ICmyNet.Flow: NetFlow based traffic investigation, analysis, and reporting", NOC Tool Workshop & 4th TF-NOC meeting, 11-12. October 2011, Brussels, Belgium
3. (b) **Slavko Gajin**, "DNS domains and servers testing", NOC Tool Workshop & 4th TF-NOC meeting, 11-12. October 2011, Brussels, Belgium
4. (b) **Slavko Gajin**, "Monitoring and analyzing audio, video, and multimedia traffic on the network", NOC Tool Workshop & 4th TF-NOC meeting, 11-12. October 2011, Brussels, Belgium
5. (b) **Slavko Gajin**, "Network Monitoring System", SIRIKT 2010, 14-17. April 2010., Kranjska gora, Slovenija
6. (b) **Slavko Gajin**, "Network monitoring - NetIS", The Third CEENet Workshop on Network Management - NATO Advanced Networking Workshop "Networking the Future", 22 – 25. September 2002, Zagreb, Hrvatska

Predavanja po pozivu i tutorijali na skupovima nacionalnog značaja:

1. (b) **Slavko Gajin**, "Pristup i servisi Interneta", Naučno stručni skup INFORMATIKA 96, Beograd, 07.05.1996. god. , (M62)
2. (b) **Slavko Gajin**, "Sigurnost i zaštita u računarskim mrežama", Stručni skup, **Zaštita** podataka u računarskim mrežama i sistemima, Beograd, 1995. , (M62)
3. (b) **Slavko Gajin**, "Neki aspekti sigurnosti UNIX operativnih sistema", Stručni skup, Zaštita podataka u računarskim mrežama i sistemima, Beograd, 1995., (M62)

Disertacije:

1. **Slavko Gajin**, "Analiza adaptivnosti modela zaokreta u čvrstospregnutim multiračunarskim mrežama", magistarska teza, ETF, Beograd, 1999. (M72)
2. **Slavko Gajin**, "Opšti model determinističkog rutiranja u multiračunarskim mrežama" doktorska teza, ETF, Beograd, 2007. (M71)

3. Nastavna delatnost

Slavko Gajin je angažovan u nastavi na Elektrotehničkom fakultetu Univerziteta u Beogradu od 2008. godine, kao docent na osnovnim studijama na studijskom programu za Elektrotehniku i računarstvo, modul Računarska tehnika i informatika, i studijskom programu za Softversko inženjerstvo, na predmetu Računarske mreže 1, a kasnije i na master studijama na predmetu Projektovanje računarskih mreža. Pri preuzimanju ovih predmeta, inoviran je nastavni plan i program, ali je i kasnije tokom ovog perioda unapređivao gradivo prema aktuelnim tehnološkim trendovima i potrebama iz inženjerske prakse. Posebno je značajno što je metodika nastave unapređena sprovođenjem savremene tzv. *blended learning* metode, koja kombinuje klasičnu nastavu u učionici, koja se na osnovnim studijama u potpunosti odvija prema predviđenom rasporedu i obimu predavanja, sa on-line nastavom koristeći eLearning platformu. Od 2009. godine laboratorijske veže, kolokvijumi i završni ispiti se polažu elektronski (na računarima uz prisustvo dežurnog asistenta), kombinovanjem većeg broja metodički osmišljenih teorijskih pitanja i rešavanjem zadataka. Ovaj način rada kod studenata je naišao na odličan prijem, što je rezultovalo i dobrom prolaznošću.

Prosečne ocene na studentskim anketama u poslednjih 5 školskih godina su priložene u sledećoj tabeli:

Školska godina	Prosečna ocena
2012/2013	4.50
2013/2014	4.48
2014/2015	4.52
2015/2016	4.46
2016/2017	4.40
Ukupna prosek:	**4.47**

U dosadašnjem opusu bio je mentor na 21 završnom radu na petogodišnjim studijama, na 20 završnih radova na četvorogodišnjim studijama, na 27 završna radova na master strudijama, 1 završnom radu na magistarskim studijama i 1 završnom radu na doktorskim studijama, kao i učesnik u komisijama za odbranu završnih radova na svim nivoima studiranja.

Ukupan broj bodova ostvaren po osnovu rukovođenja završnim radovima dat je u narednoj tabeli:

Rukovođenje izradom završnih radova	Broj studenata	Koeficijenti	Bodovi
Osnovne studije (petogodišnje)	21	1.5	31.5
Osnovne studije (četvorogodišnje)	20	1	20
Master studije	27	2	54
Magistarske studije	1	4	4
Doktorske studije	1	8	8
Ukupno			**117.5**

4. Profesionalna delatnost i društvena aktivnost

Slavko Gajin je nacionalni predstavnik u stručnom telu „e-Infrastructure Reflection Group" (e-IRG, www.e-irg.eu), koje ima savetodavnu ulogu Evropske komisije u oblasti elektronskih infrastruktura

5. Priznanja i nagrade

1. Plaketa Društva za informatiku Srbije za izvanredan doprinos u razvoju informatike u 2002. godini (projekat NetIS, Računarski centar Univerziteta u Beogradu).

dr Slavko Gajin, detaljan spisak radova

- Autor poglavlja u knjizi međunarodnog značaja:

  1. Slavko Gajin, Chapter 2, "Video services in Serbia's Academic Network", book: "Video Conference as a tool for Higher Education", Firenze University Press, 2012, ISBN 978-88-6655-102-7, (M14)

- Radovi u međunarodnim naučnim časopisima sa impakt faktorom:

  1. Slavko Gajin, Zoran Jovanovic, "An Accurate Performance Model for Network-on-Chip and Multicomputer Interconnection Networks", Journal of Parallel and Distributed Computing, October 2012, Volume 72, Issue 10, p. 1280–1294, ISSN: 0743-7315, DOI: 10.1016/j.jpdc.2012.05.005, IF(2011)= 0.859, (M23)
  2. Slavko Gajin, Zoran Jovanović, "Explanation of Performance Degradation in Turn model", The Journal of Supercomputing, 37, 271-295, September 2006., Vol. 37, Issue 3, p. 271-295, Online ISSN 0920-8542, DOI: 10.1007/s11227-006-6454-y, IF(2006)= 0.398, (M23)
  3. N. Ninković, S. Gajin, I. Reljin, Packet Dispersion Strategy Evaluation from the Perspective of Packet Loss Pattern and VoIP Quality, COMPUTER SCIENCE AND INFORMATION SYSTEMS - COMSIS, p. 1-23, 2015. DOI: 10.2298/CSIS150120043N, IF(2016)= 0.837, (M23)
  4. Y. Abuadlla, G. Kvaščev, S. Gajin, Z. Jovanović, Flow-Based Anomaly Intrusion Detection System Using Two Stages Neural Network, Computer Science and Information Systems, COMPUTER SCIENCE AND INFORMATION SYSTEMS - COMSIS, Vol. 11, No. 2, p. 601-622, Jun, 2014, IF(2014)=0.477, (M23)
  5. N. Ninković, Ž. Bojović, S. Gajin, A Novel Scheme for Dynamic Triggering Of Packet Dispersion, ELEKTRONIKA IR ELEKTROTECHNIKA, Vol. 20, No. 5, p. 162-169, 2014, IF(2014)=0.561, (M23)
  6. B. Jovanović, S. Gajin, An efficient mechanism of cryptographic synchronization within selectively encrypted H.265/HEVC video stream, Multimedia Tools and Applications, p. 1-17. https://doi.org/10.1007/s11042-017-4389-3, 2017, IF(2014)=1.530, (M22)
  7. V. Blagojević, D. Bojić, M. Bojović, M. Cvetanović, J. Đorđević, Đ. Đurđević, B. Furlan, S. Gajin, Z. Jovanović, D. Milićev, V. Milutinović, B. Nikolić, J. Protić, M. Punt, Z. Radivojević, Ž. Stanisavljević, S. Stojanović, I. Tartalja, M. Tomašević, P. Vuletić, A Systematic Approach to Generation of New Ideas for PhD Research in Computing, ADVANCES IN COMPUTERS, Vol. 104, p. 1-31, 2017, IF(2014)=0.789 (M23)

- Radovi prezentovani ili objavljeni u zbornicima radova na međunarodnim naučnim skupovima:

  1. Slavko Gajin, European Cloud Collaboration Through GEANT, 16th RoEduNet Conference: Networking in Education and Research, 21-23 September, 2017, Targu Mures, Romania (M32)
  2. Valentina Timčenko, Slavko Gajin, "Machine Learning based Network Anomaly Detection for IoT environments", 8th International Conference on Information Society and Techology - ICIST, Kopaonik, 2018 0 (M33)
  3. Valentina Timčenko, Slavko Gajin, "Ensemble classifiers for supervised anomaly based network intrusion detection", IEEE 13th International Conference on Intelligent Computer Communication and Processing (ICCP 2017), September 7 - 9, 2017 in Cluj-Napoca, Romania, ISBN: 978-1-5386-3367-0 (M33)

4. Juma Ibrahim, Slavko Gajin, „Intrusion Detection System SDN-Based, Literature review", 16th International Conference INFOTEH-JAHORINA, Bosnia and Hercegovina, Vol. 16, March 2017, p. 621-624, ISBN 978-99976-710-0-4 (M33)
5. Mihailo Vesović, Hasan Redžović, Slavko Gajin, "Evaluation of Netmap framework for MPLS protocol implementation", 3rd International Conference on Electrical, Electronic and Computing Engineering IcETRAN 2016 (M33)
6. Hasan Redžović, Aleksandra Smiljanić, Slavko Gajin, "Performance evaluation of open-source VPN software implementations", 3rd International Conference on Electrical, Electronic and Computing Engineering IcETRAN 2016 (M33)
7. Gajin, S., Hackett, R., Galeazzi, F., Pagaime, J. "A strategic approach to providing cloud services for research and education community", ICIST 2015 Proceedings Vol.2, pp.358-363, 2015 (M34)
8. Marko Mišić, Slavko Gajin, Korišćenje Mininet okruženja za simulaciju softverski definisanih mreža, 22nd Telecommunications Forum, TELFOR 2014 (25.11.2014 - 27.11.2014) (M33)
9. Slavko Gajin, Petar Bojović: "Monitoring, analyzing and cleaning DNS configuration errors across European NRENs", TERENA Networking Conference 2013, Mastricht, Netherlands, 2.-6. Jun 2013, (M32)
10. Mirjana Devetaković, Mila Pucar, Slavko Gajin, „A Knowledge Base supporting the Technological Research Project TR36035 on Climate Changes and Urban Development", ICIST 2013 - 3rd International Conference on Information Society Technology and Management, Kopaonik 2013. god., (M34)
11. M Savic, S Gajin, M Bozic, "SNMP based Grid infrastructure monitoring system", IEEE MIPRO, 2011 Proceedings of the 34th International Convention, p. 231-235, (M31)
12. Slavko Gajin, Vedrin Jeliazkov, Constantinos Kotsokalis, Yannis Mitsos: "Seamless Integration of Network Management Tools in a Multi-Domain Environment", Integrated Network Management, 2007. IM'07. 10th IFIP/IEEE International Symposium on. IEEE, 2007. p. 745-748., (M34)
13. Zoran Jovanović, Slavko Gajin, Mara Bukvic, Pavle Vuletic, Djordje Vulović: The Optical NREN of Serbia and Montenegro - New Solutions in Infrastructure and Monitoring, u "One step ahead", The 20th Trans European Research and Education Networking Conference, June 7-10, 2004, Rhodes, Greece, Selected Papers, ISBN 90-77559-04-3, http://www.terena.org/publications//tnc2004-proceedings/, (M31)
14. Z. Jovanović, S. Gajin, M. Bukvic, P. Vuletic, Dj. Vulović: The optical NREN of Serbia and Montenegro, Fourth Yugoslavia-Japan Joint Workshop on Computer Simulation Science (3JW), September 2004, Tara, Yugoslavia, (M31)
15. Z. Jovanović, S. Gajin: "Simulation of the Turn Model" First Yugoslavia-Japan Joint Workshop on Computer Simulation Science (3JW), 1-2 September 2000., Belgrade, Yugoslavia, (M31)

Radovi u domaćim časopisima:

1. Zoran Jovanović, Igor Milojevic, Slavko Gajin, Milan Vitorović "Sigurnost unix operativnih sistema", Infoscience 04/96, 1996. (M52)

Radovi u zbornicima radova domaćih skupova:

1. Pavle Vuletic, Slavko Gajin, „Uticaj QUIC protokola na tradicionalne mehanizme nadgledanja mrežnih tokova", 62. konferenciju za elektroniku, telekomunikacije, računarstvo, automatiku i nuklearnu tehniku, ETRAN 2018. (M63)

2. Petar Bojović, Slavko Gajin, "Testiranje i analiza funkcionalnosti internet domena Republike Srbije", YUINFO 2013, Kopaonik 2013. god. (M63)
3. Bojan Mitrovic, Mirjana Devetaković, Slavko Gajin, Ljiljana Petruševski, "Unapređenje AMRES e-learning sistema novim funkcionalnostima – aformat modul", YUINFO 2011, Kopaonik, 2011. god. (M63)
4. Mirjana Devetaković, Slavko Gajin, Bojan Mitrović, "Portal Akademske mreže Srbije za podršku elektronskom učenju", YUINFO 2010, Kopaonik, 2010. god., (M63)
5. S. Gajin, D. Pajin, D. Novaković, "Sistem za nadgledanje računarske mreže-NetIIS", YUINFO 2006, Kopaonik, 6-10.3.2006. god. (M63)
6. Slavko Gajin, Pavle Vuletić, "Trendovi u razvoju i primeni računarskih mreža", Informatika 2004, Beograd, 2004. god. (M63)
7. Slavko Gajin, "Razvoj EDI aplikacija na Internetu", YU INFO '97, Brezovica, 04-07. april 1997. god. (M63)
8. Slavko Gajin, "Sigurnosni mehanizmi u protokolu za nadzor i upravljanje mrežom", naučno stručni skup Informacione tehnologije (IT '96), Žabljak, 11-15. mart 1996. god., (M63)
9. Slavko Gajin, "OSISS - Otvoren sistem implementacije sigurnosnih servisa", naučno stručni skup Informacione tehnologije (IT '96), Žabljak, 11-15. mart 1996. god., (M63)
10. Slavko Gajin, "Distribucija ključeva u OSISS okruženju", naučno stručni skup Informacione tehnologije (IT '96), Žabljak, 11-15. mart 1996. god., (M63)
11. Slavko Gajin, "OSISS - Otvoren sistem implementacije sigurnosnih servisa", YU INFO '96, Brezovica, 02-05. april 1996. god., (M63)
12. Slavko Gajin, "Model alternacije zaokreta kod rešetke", YU INFO '95, Brezovica, 04--07. april 1995 god. (M63)
13. Slavko Gajin, "Poboljšanje algoritma rutiranja u čvrstospregnutim multiračunarskim mrežama", XXXVIII konferencija ETRAN, Niš, 07-09. jun 1994. god., (M63)

Predavanja po pozivu ili tutorijali na međunarodnim stručnim skupovima:

1. Slavko Gajin, "Monitoring and analyzing audio,video, and multimedia traffic on the network", Campus network monitoring workshop, 24–25. April 2012, Brno, Czech Republic
2. Slavko Gajin, "ICmyNet.Flow: NetFlow based traffic investigation, analysis, and reporting", NOC Tool Workshop & 4th TF-NOC meeting, 11-12. October 2011, Brussels, Belgium
3. Slavko Gajin, "DNS domains and servers testing", NOC Tool Workshop & 4th TF-NOC meeting, 11-12. October 2011, Brussels, Belgium
4. Slavko Gajin, "Monitoring and analyzing audio, video, and multimedia traffic on the network", NOC Tool Workshop & 4th TF-NOC meeting, 11-12. October 2011, Brussels, Belgium
5. Slavko Gajin, "Network Monitoring System", SIRIKT 2010, 14-17. April 2010., Kranjska gora, Slovenija
6. Slavko Gajin, "Network monitoring - NetIS", The Third CEENet Workshop on Network Management - NATO Advanced Networking Workshop "Networking the Future", 22 – 25. September 2002, Zagreb, Croatia

Predavanja po pozivu i tutorijali na skupovima nacionalnog značaja:

1. Slavko Gajin, "Pristup i servisi Interneta", Naučno stručni skup INFORMATIKA 96, Beograd, 07.05.1996. god. , (M62)

2. Slavko Gajin, "Sigurnost i zaštita u računarskim mrežama", Stručni skup, Zaštita podataka u računarskim mrežama i sistemima, Beograd, 1995. , (M62)
3. Slavko Gajin, "Neki aspekti sigurnosti UNIX operativnih sistema", Stručni skup, Zaštita podataka u računarskim mrežama i sistemima, Beograd, 1995., (M62)

Disertacije:

1. Slavko Gajin, "Analiza adaptivnosti modela zaokreta u čvrstospregnutim multiračunarskim mrežama", magistarska teza, ETF, Beograd, 1999. (M72)
2. Slavko Gajin, "Opšti model determinističkog rutiranja u multiračunarskim mrežama" doktorska teza, ETF, Beograd, 2007. (M71)

Kandidat je učesnik sledećih projekata tehnološkog razvoja Ministarstva prosvete, nauke i tehnološkog razvoja:

1. Projekta razvoja visokog obrazovanja Ministarstva prosvete nauke i tehnološkog razvoja – „Unapređenje nastave na predmetima iz oblasti računarskih mreža i zaštite podataka", decembar 2017 – maj 2018.
2. „Prostorni, ekološki, energetski i društveni aspekti razvoja naselja i klimatske promene – međusobni uticaju", evidencioni broj 36035, 2011-danas. god.
3. "Razvoj kompjuterskih metoda i softvera za modeliranje i simulacije u oblasti opšteg i biomedicinskog inženjeringa", 2005-2007. god.
4. "Projekat realizacije integralnog informacionog sistema i monitoringa računarske mreže", evidencioni broj 1-253, 2002.-2004. god.
5. "Opšti elementi i posebne primene zaštite podataka u računarskim sistemima i mrežama", evidencioni broj S.1.02.05.0163, 1997.-2000. god.

Kandidat je učesnik sledećih međunarodnih projekata:

1. H2020 GN4-phase2 - "Multi-Gigabit European Research and Education Network and Associated Services", Grant Agreement No. 731122, 1.5.2016. – 31.12.2018., www.geant.org, član tima
2. H2020 GN4 - "Multi-Gigabit European Research and Education Network and Associated Services", Grant Agreement No. 691567, 1.5.2015. - 30.8.2016, www.geant., član tima
3. FP7 GN3plus - "Multi-Gigabit European Research and Education Network and Associated Services", 1.4.2013.-31.3.2015., www.geant.net, zamenik rukovodioca tima
4. FP7 GN3 - "Multi-Gigabit European Research and Education Network and Associated Services", 1.4.2009.-31.3.2013., www.geant.net, zamenik rukovodioca tima
5. FP7 SEERA-EI – "SouthEast European Research Area - e-Infrastructure", 1.4.2009.-31.3.2012., www.seera-ei.eu, član projektnog tima
6. TEMPUS ViCES - "Video Conferencing Educational Services", 144650-TEMPUS-2008-IT-JPGR, 2009. - 2011. god., vices.marnet.net.mk, rukovodilac tima
7. FP6 SEEREN2 – "South-Eastern European Research & Education Network", oktobar 2006. - april 2008. god., www.seeren.org, rukovodilac tima
8. FP6 SEEFIRE – South-East Europe Fibre Infrastructure for Research and Education", 2005.-2006. god., www.seefire.org, rukovodilac tima
9. FP6 SEEGRID –"South-Eastern European GRID-enabled eInfrastructure Developement", 1.5.2004. - 30.4.2006., www.see-grid.org, član projektnog tima
10. FP6 SEEGRID2 – "South-Eastern European GRID-enabled eInfrastructure Developement 2", 2006-2008. god., www.see-grid.eu, član projektnog tima

11. FP5 SEEREN – "South-Eastern European Research & Education Networking", 2002. - 2004. god., www.seeren.org, rukovodilac tima
12. ELISA –"E-learning for improving access to Infomation Society for SMEs in the SEE Area" (INTERREG III B CADSES project), 2005-2008. god., www.elisa-project.net, član projektnog tima.

Kandidat je rukovodilac ili učesnik sledećih stručnih projekata ETF-a:

1. Razvoj, implementacija i održavanje informacionog sistema za obračun i naplatu električne energije, RTV pretplatu i pružanje elektrodistributivnih usluga potrošačima, EDB, 2006-danas
2. Matična evidencija osiguranih lica, RFZO, 2002–danas
3. Elektronsko fakturisanje lekova i pomagala propisanih na teret sredstava Republičkog zavoda za zdravstveno osiguranje, RFZO, 2002–danas
4. Elektronska evidencija propisanih i izdatih lekova pod specijalnim režimom izdavanja, RFZO, 2002–danas
5. Zdravstveni informacioni sistem primarne zdravstvene zaštite, 2005–danas
6. Razvoj, implementacija i održavanje Informacionog sistem za magacinsko, materijalno i pogonsko knjigovodstvo, NBS-ZIN, 2009-danas
7. Razvoj, implementacija i održavanje informacionog sistema za praćenje proizvoda NBS-ZIN od posebnog interesa, NBS-ZIN, 2007–2013
8. Podsistem za podršku rada pisarnice Republičkog zavoda za zdravstveno osiguranje, 2009–danas
9. Razvoj, implementacija i održavanje Opštinskog informacionog sistema – OpIS, 2000-danas (35 opština)
10. Razvoj, implementacija i održavanje Softverskog sistema za evidenciju matičnih knjiga, 2004-danas (33 opštine)
11. Informacioni sistem i monitoring računarskih mreža – NetIIS, 2002-danas
12. Testiranje DNS domena, RNIDS, 2012. god.

УНИВЕРЗИТЕТ У БЕОГРАДУ

ЕЛЕКТРОТЕХНИЧКИ ФАКУЛТЕТ
БЕОГРАД

ПРИМЉЕНО 04 ОКТ 2018

Орг. јед.	Број	Прилог	Вредност
	1451/11		

Студентски трг 1, 11000 Београд, Република Србија
Тел.: 011 3207400; Факс: 011 2638912; E-mail: officebu@rect.bg.ac.rs

ВЕЋЕ НАУЧНИХ ОБЛАСТИ
ТЕХНИЧКИХ НАУКА

Београд, 24.9.2018. године
02 број: 61202-4285/2-18
ЛД

На основу чл. 75. ст 2. Закона о високом образовању ("Службени гласник РС", број: 88/17), чл. 48. ст. 5. тач. 1. Статута Универзитета у Београду ("Гласник Универзитета у Београду", број 201/18), чл. 13. ст. 1. Правилника о већима научних области на Универзитету у Београду ("Гласник Универзитета у Београду", број 134/07, 150/09, 158/11, 164/11, 165/11, 180/14, 195/16 и 197/17), чл. 24. ст. 1. тач. 1. Правилника о начину и поступку стицања звања и заснивања радног односа наставника Универзитета у Београду ("Гласник Универзитета у Београду", број 200/17) и Правилника о минималним условима за стицање звања наставника на Универзитету у Београду ("Гласник Универзитета у Београду", број 192/16, 195/16, 197/17 и 199/17), а на предлог Изборног већа Електротехничког факултета, број: 1451/8 од 11. септембра 2018. године, Веће научних области техничких наука, на седници, одржаној 24. септембра 2018. године, донело је

О Д Л У К У

БИРА СЕ **др Славко Гајин**, у звање ванредног професора за ужу научну област Рачунарска техника и информатика.

О б р а з л о ж е њ е

Универзитет у Београду – Електротехнички факултет је дана 4. јула 2018. године, у публикацији „Послови", објавио конкурс за избор у звање ванредног професора, за ужу научну област Рачунарска техника и информатика, због истека изборног периода.

Извештај Комисије за припрему извештаја о пријављеним кандидатима стављен је на увид јавности дана 27. августа 2018. године, на сајту Факултета.

На основу предлога Комисије за припрему извештаја о пријављеним кандидатима, Изборно веће Електротехничког факултета, на седници одржаној 11. септембра 2018. године, донело је одлуку о утврђивању предлога да се кандидат др Славко Гајин изабере у звање ванредног професора.

Факултет је дана 17. септембра 2018. године доставио Универзитету комплетан захтев за избор у звање на прописаним обрасцима.

Универзитет је комплетну документацију коју је доставио Факултет ставио на web страницу Универзитета, дана 17. септембра 2018. године.

Веће научних области техничких наука, на седници одржаној дана 24. септембра 2018. године, разматрало је захтев Факултета и утврдило да кандидат испуњава услове прописане чл. 74. и 75. Закона о високом образовању и чланом 135. Статута Универзитета у Београду, као и услове прописане Правилником о минималним условима за стицање звања наставника на Универзитету у Београду, па је донета одлука као у изреци.

ПРЕДСЕДНИК ВЕЋА

Проф. др Јован Филиповић

Доставити:
- Факултету (2),
- Архиви Универзитета (1).

ЕЛЕКТРОТЕХНИЧКИ ФАКУЛТЕТ
(назив послодавца)
БЕОГРАД, Булевар краља Александра 73
(седиште послодавца)
1451/12
(број)
08 ОСТ 2018
(датум)

На основу чланова 24 став 1, 27 и 30 Закона о раду ("Службени гласник РС", број 24/2005, 61/2005, 54/2009, 32/2013 и 75/2014, 13/2017 – одлука УС и 113/2017) и на основу члана 73 Закона о високом образовању Службени гласник РС", бр. 88/2017) закључује се:

УГОВОР О РАДУ

1. ЕЛЕКТРОТЕХНИЧКИ ФАКУЛТЕТ – Булевар краља Александра 73 (у даљем тексту:
(назив и седиште послодавца)
послодавац) заснива радни однос са:
др Славком Гајином, из Београда, Нодилова 7/15
(име и презиме запослене, место пребивалишта, односно боравишта)
0407974880035 (ЈМБГ) доктор електротехничких наука, VIII степен (стручни,академски, научни назив)

2. Радни однос се заснива за обављање послова у звању **ванредног професора**, са следећим описом послова:
- извођење предавања и вежби на I, II i III степену студија;
- припрема и извођење предавања и вежби, као и других облика наставе;
- рад на изради и осавремењавању наставних планова и програма студија које се остварују на Факултету;
- праћење и примена новина у области наставних метода;
- припрема и обављање испита;
- консултације са студентима;
- обављање осталих облика наставе који су предвиђени програмом наставног предмета;
- организовање појединачног и заједничког научног рада са студентима;
- менторство у изради дипломских радова;
- менторски рад са студентима магистарских, односно докторских студија;
- учешће у раду комисије за одобравање, оцену или одбрану магистарског рада, односно докторске дисертације;
- остваривање наставе на студијама за иновацију знања, као и на студијама за остваривање програма стручног усавршавања;
- иновације у настави;
- сарадња са сарадницима у току остваривања свих облика наставе;
- учешће у раду катедре, научно-наставног већа, изборног већа и других стручних органа и комисија Факултета
- обавља и друге послове везане за научно-наставни процес као и послове и задатке које му декан и стручни органи Факултета ставе у задатак у складу са својим знањем и потребама Факултета.

Катедра за рачунарску технику и информатику
(организациона јединица)

3. Запослени ће обављати послове у Београду (седишту послодавца).

4. Запослени заснива радни однос на:
   1) неодређено време, почев од
   (датум заснивања радног односа)
   2) одређено време од **01.10.2018.** до **30.09.2023.** у трајању од 5 година
   (месеци, година)

5. Запослени заснива радни однос са непуним радним временом, у трајању од 10
(пуним или непуним) (бр. часова недељно)

6. Запослени је дужан да ступи на рад **01.10.2018. год.**
(дан, месец и година почетка рада)

7. Запослени прихвата да у току рада може да буде распоређен на друге послове у складу са законом и општим актом о раду послодавца.

8. Запослени има право на зараду за обављени рад и време проведено на раду. Елементи који одређују зараду запосленог су:
S = 2,700 бодова,
K_1 = 25 бод/год.,
На дан 01.10.2018. год. запосленом се признаје Z = 0 година проведених у звању, односно струци. Основица (S*1000 + K) износи 3030 бодова. Промена Z се рачуна од 01.10.2019. године.
Послодавац се обавезује да запосленом приликом сваке исплате зараде и накнаде зараде, достави писмени обрачун, у складу са Законом.

9. Запослени има право на увећану зараду у складу са законом, колективним уговором и општим актом послодавца.

10. Запослени има право на зараду из добити Послодавца сагласно општем акту послодавца.

11. Запослени има право на накнаду зараде и друга примања у складу са законом, колективним уговором и општим актом послодавца. Запосленом се зарада и друга примања исплаћују у роковима утврђеним општим актом послодавца.

12. Занослени има право на накнаду трошкова превоза:

- за долазак и одлазак са рада,
- за време проведено на службеном путу у земљи и иностранству

у складу са законом и општим актом послодавца.

13. Запослени има право на одмор у току рада, на дневни, недељни и годишњи одмор у складу са законом и општим актом послодавца. О времену коришћења годишњег одмора одлучује послодавац уз претходну консултацију запосленог.

14. Запослени има право на плаћено одсуство у случају:

- склапања брака – 5 радних дана,
- порођаја супруге – 5 радна дана,
- теже болести или смрти члана уже породице – 5 радна дана,
- добровољног давања крви – 2 узастопна дана рачунајући и дан давања крви,
- за приватне потребе по одобрењу декана – до 2 радна дана.

За дане плаћеног одсуства запослени прима накнаду у висини зараде коју би остварио да је у те дане радио.

15. Запослени је одговоран за штету коју је на раду или у вези са радом – намерно или из крајње непажње, прозроковао послодавцу.

16. Послодавац може отказати уговор о раду запосленом ако крши радне обавезе, и то:

- ако је утврђено да не остварује резултате рада;
- ако је утврђено да нема потребна знања и способности за обављање послова на којима ради;
- ако не поштује радну дисциплину, односно ако је његово понашање такво да не може да настави рад код послодавца;
- ако учини доступним или саопшти садржај испитних задатака и решења пре термина одржавања испита;
- ако злоупотреби право на одсуство због привремене спреченоети за рад;
- ако незаконито располаже средствима;
- ако повреди прописе о заштити од пожара, експлозије, елементарних непогода и штетних деловања отровних и других опасних материја, као и повреда прописа и ненредузимања мера ради заштите запослених, средстава рада и животне средине;
- ако ода пословну, службену или другу тајну утврђену законом или општим актом послодавца као и одавање података из тендерске документације коју подноси факултет по расписаној јавној набавци;
- ако ода пословну, службену или другу тајну утврђену законом или општим актом послодавца;
- ако одбије да обавља послове на које је распоређен;
- ако нецелисходно и несодговорно користи средства рада;
- ако фалсификује новчана и друга документа;
- ако изазове већи неред или тучу на раду;
- ако чешће долази на рад у напитом стању или употребљава алкохол или наркотик за време рада, које смањује способност за рад или омета процес рада;
- ако не достави потврду о привременој спречености за рад у року од три дана;
- ако злоупотреби радну обавези у намери да за себе или другог прибави имовинску корист; односно свако друго незаконито и несовлашћено понашање са наведеном намером;
- ако проневери или украде имовину факултета.

17. Ако запослени претрпи повреду или штету на раду или у вези са радом, послодавац је дужан да му накнади штету, у складу са Законом и општим актом.

Послодавац одговара за штету коју одговорно лице или запослени вршећи злостављање проузрокује другом запосленом код истог послодавца, у складу са Законом о спречавању злостављања на раду.

Запослени који врши злостављање, као и занослени који злоупотреби право на заштиту од злостављања, одговоран је за непоштовање радне дисциплине, односно повреду радне дужности.

18. Послодавац се обавезује да одмах по ступању запосленог на рад поднесе прописане пријаве на обавезно социјално осигурање и да благовремено уплаћују одговарајуће доприносе, у складу са законом.

19. Запослени је дужан да се придржава прописаних мера заштите на раду.

20. Послодавац је дужан да обезбеди услове рада и организује рад којим се обезбеђује заштита живота и здравља заносленог, у складу са законом и другим прописима.

21. Запослени и послодавац прихватају сва права, обавезе и одговорности утврђене законом и општим актом послодавца.

22. Запослени може послодавцу да откаже уговор о раду у писаној форми у року од 15 дана пре дана наведеног као дан престанка радног односа (отказни рок).

23. Све спорне ситуације из овог уговора, уговорне стране ће решавати споразумно. У случају спора, надлежан је стварно надлежни суд у Београду.

24. Свака од уговорних страна може да откаже овај уговор, под условима и случајевима утврђеним законом.

25. Овај уговор је сачињен у 4 (четири) истоветна примерка, од којих 1 (један) примерак задржава запослени, а 3 (три) послодавац.

ЗАПОСЛЕНИ

Slađana Gajić

ЗА ПОСЛОДАВЦА

Prof. dr Božo Krstajić. redovni profesor

- **Kratka biografija**

Rođen je 7. aprila 1968. god. u Žabljaku, gdje je završio osnovnu školu i prva dva razreda srednjeg usmjerenog obrazovanja. Srednju školu je završio u gimnaziji "Slobodan Škerović" u Podgorici.Na Elektrotehničkom fakultetu u Podgorici je diplomirao marta 1992. godine sa prosječnom ocjenom 9,87, a diplomski rad "YAMABICO - upravljanje mobilnim robotom" je odbranio sa ocjenom 10. Dobitnik je studentske nagrade "19. decembar" i Plakete Univerziteta kao najbolji student Univerziteta 1991. god. Postdiplomske studije je upisao na istom fakultetu 1992. godine, na Odsjeku robotike i vještačke inteligencije. Ispite na postdiplomskim studijama je položio sa prosječnom ocjenom 10, a magistarski rad pod nazivom "Modifikovani adaptivni LMS algoritmi" je odbranio 1996. godine. Doktorsku disertaciju, pod nazivom "Novi pristup LMS adaptivnom algoritmu sa promjenljivim korakom", odbranio je 20. 12. 2002. godine na Elektrotehničkom fakultetu u Podgorici.

U zvanje docenta je izabran 09.07.2003. godine, u zvanje vanrednog profesora 02.10.2008. godine, a zvanje redovnog profesora 19.12.2013. godine na Univerzitetu Crne Gore. Bio je visiting profesor od 2004. do 2007. godine na univerzitetu "Luigi Gurakuqi" u Skadru, Albaniji. Bio je direktor Centra informacionog sistema UCG od 2003. do 2015. godine.

Autor je ili koautor dvije monografije, više udžbenika za osnovnu školu iz oblasti informatike i više autorizovanih skripti za potrebe nastave na predmetima na kojima je angažovan. Do sada je objavio preko 100 naučnih i stručnih radovan u časopisima i na konferencijama. Mentor je na 1 doktorskom radu i 3 magistarska rada, a pod njegovim mentorstvom su uspješno završena: 3 doktorska, 14 magistarskih i preko 150 diplomskih i specijalističkih radova. Recenzirao je više naučnih radova u istaknutim svjetskim časopisima iz oblasti adaptivnih algoritama i računarskih sistema.

Koordinirao je i učestvovao u više značajnih evropskih projekata kao predstavnik Univerziteta Crne Gore, a koje finansira Evropska unija u okviru FP6, FP7, TEMPUS, IPA i H2020 programa (SEEREN2, SEE-GRID2, SEE-GRID-SCI, SEERA-EI, GEANT3, NQF&QHE, GEANT3+, HPSEE, EGI-Inspire, DL@WEB, RINGINDEA, FORSEE, CONGRAD, GN4 i VI-SEEM). Angažovan je od strane više kompanija i institucija u Crnoj Gori i van nje kao stručni ICT konsultant ili projektant, te je projektovao i realizovao više značajnih stručnih projekata. Od strane sudova u Crnoj Gori je angažovan kao sudski vještak za oblast ICT-a.

Predsjednik je organizacionog i programskog odbora domaćeg naučno-stručnog skupa »INFORMACIONE TEHNOLOGIJE« koja se već 24 godine organizuje i editor je zadnjih 10 zbornika ove konferencije. Takodje je član programskih odbora dvije međunarodne konferencije: "Balkan Conference in Informatics" i "RoEduNet Conference: Networking in Education and Research" kao i član Predsjedništva ETRAN-a. Član je međunarodne asocijacije elektro inženjera – IEEE, inženjerske komore Crne Gore, Internet zajednice ISOC i Ubuntu zajednice Crne Gore. Menadžer je lokalne CISCO akademije.Pokretač je MREN-a (Montenegrin Research and Education Network) i član njegovog upravnog odbora. Osnivać je prvog IXP-a u Crnoj Gori (MIXP).
Govori engleski jezik, a služi se i ruskim jezikom.

- **Najvažnije i najsvježije reference iz oblasti doktorata** (radovi 1,2,3,4, 5, 6, 7 i 8 su u časopisima sa SCI liste)**:**

1. T. Popovića, N. Latinović, A. Pešić, Ž. Zečević, **B. Krstajić** i S. Djukanović.

monitoring: A case study", Computers and Electronics in Agriculture, Vol. 140, August 2017, pp 255-265, ISSN 0168-1699, doi.org/10.1016/j.compag.2017.06.008, Elsevier

2. L. Filipović and **B. Krstajić**, "Combined Load Balancing Algorithm in Distributed Computing Environment", ISSN 1392–124X (print), INFORMATION TECHNOLOGY AND CONTROL, 2016,T.45, Nr.3, DOI: 10.5755/j01.itc.45.3.13084
3. L. Filipović, D. Mrdak and **B. Krstajic, „**Performance evaluation of parallel DNA multigene sequence analysis", Comptes rendus de l'Académie bulgare des sciences, Vol 69, No. 4, 2016. pp.489-496. Print ISSN 1310-1331, Online ISSN 2367-5535.
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7. **B. Krstajić**, Ž. Zečević and Z. Uskoković, » Increasing convergence speed of FxLMS algorithm in white noise environment " AEU-INTERNATIONAL JOURNAL OF ELECTRONICS AND COMMUNICATIONS, DOI: 10.1016/j.aeue.2013.04.012, (ISSN:1434-8411), publikovan online 2013., Elsevier
8. T. Popović, M. Kezunović and **B. Krstajić**, »Smart grid data analytics for digital protective relay event recordings", INFORMATION SYSTEMS FRONTIERS, DOI: 10.1007/s10796-013-9434-9, (ISSN: 1387-3326, online ISSN 1572-9419),2013., Springer..
9. L. Filipović, D. Mrdak and **B. Krstajić, „**Performance Evaluation of Computational Phylogeny Software in Parallel Computing Environment", ICT Innovations 2012 Advances in Intelligent Systems and Computing, volume 207, pp 255-264, DOI: 10.1007/978-3-642-37169-1_25, (ISSBN 978-3-642-37168-4, online ISSBN 978-3-642-37169-1), 2013., Springer..
10. L.Filipović, **B. Krstajić**, „Modified master-slave algorithm for load balancing in parallel applications", ETF Journal of ELECTRICAL ENGINEERING, vol. 20, No.1, pp. 74-83, 2014.

УНИВЕРЗИТЕТ ЦРНЕ ГОРЕ

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Датум, 19.12.2013 г.

Ref:
Date,

Na osnovu člana 75 stav 2 Zakona o visokom obrazovanju (Sl.list RCG, br. 60/03 i Sl.list CG, br. 45/10 i 47/11) i člana 18 stav 1 tačka 3 Statuta Univerziteta Crne Gore, Senat Univerziteta Crne Gore, na sjednici održanoj 19.12.2013. godine, donio je

O D L U K U
O IZBORU U ZVANJE

Dr BOŽO KRSTAJIĆ bira se u akademsko zvanje **redovni profesor** Univerziteta Crne Gore za predmete: Operativni sistemi, osnovne studije–ETR, Adaptivni sistemi upravljanja-specijalističke studije EA, Modelovanje i simulacija dinamičkih sistema-specijalističke studije EA, **na Elektrotehničkom fakultetu** i Automatsko upravljanje, na Mašinskom fakultetu.

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