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EDITORIAL

Introduction to the Special Issue on the French–Polish Collaboration in Mathematical Models of Computer Systems, Networks and Bioinformatics

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Abstract
On the occasion of the celebration in 2019 of the 100th anniversary of official French–Polish Scientific Collaboration, this paper explores the origins and outcomes of a scientific collaboration that we launched in the 1980s together with the late Professor Stefan Węgrzyn of the Polytechnic University of Silesia in Gliwice, Poland, Founding Director of the Institute of Theoretical and Applied Informatics of the Polish Academy of Sciences, and Fellow of the Polish Academy of Sciences. We survey the themes of this long-standing collaboration, outline the work that was accomplished, and the reasons that resulted in these themes being at its core. We outline the main scientific outcomes, and discuss the current work and projects that relate to this exemplary Franco-Polish collaboration. Finally, we introduce the papers of this Special Issue in the light of these ongoing themes.

Introduction

This paper first briefly reviews the scientific history and current status of our long-term Franco-Polish collaboration that the French-speaking Fellow of the Science Academy of Poland, the late Professor Stefan Wegrzyn (1925–2011) founder of IITIS-PAN in Gliwice, Poland, initiated with me and my team in the early 1980s.

Then the paper introduces the Special Issue on Modelling of Computer Systems, Networks and Bio-Informatics Systems.

Interestingly enough, Professor Wegrzyn's own interests in the modeling and analysis of control systems [142] and in certain aspects of bioinformatics [140], as presented in these two books, are quite in line with the directions of the present Special Issue.

When he visited me near Paris at IRIA in Rocquencourt, France, which later became the well-known research organization INRIA, Professor Wegrzyn was already collaborating with the University of Lille. Fluent in French, he also developed collaborations with the French speaking University of Sherbrooke in Canada. For his many contributions to Poland, Professor Wegrzyn was awarded the honour of Commander of the Order of Polonia Restituta. France recognized his contributions to Franco-Polish Scientific Collaboration by making him an Officer of the Ordre des Palmes Académiques of France. His scientific recognition and links to France and French-speaking Canada won him Honoris Causa Doctorates from the University of Lille, France (1973), the University of Sherbooke in Canada (1978). In Poland, he also received Honoris Causa Doctorates from his alma mater the Polytechnic University of Silesia (1988), from the AGH University of Science and Technology of Cracow (1989), and from the Polytechnic University of Rzeszow (2004).

On his first visit with us, Professor Wegrzyn was impressed with the ideas and work on Modelling Methods for Computer Systems and Networks that we were pioneering, and was persuaded to set up a similar activity at IITIS-PAN. He was successful in this initiative, with the sustained diligence of his successor as Director of IITIS, Professor Tadeusz Czachorski, who has himself actively taken part and

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developed this collaboration and continued it to this day. An important element of this success was that in France I had the good fortune to train over 35 PhD students (of a total of more than 87 that I have graduated), and many of them chose a career in academia and in research. Thus, many of the methods that I had been developing in the 1970s and 1980s in France were successfully transferred to Poland and pursued in many joint papers between my former students, such as Professors Atmaca, Jean-Michel Fourneau, Ferhan Pekergin and Nihal Pekergin, and Professor Tadeusz Czachorski and his other collaborators in Poland.

In the sequel, we will first go over a certain number of areas that contributed to this collaboration, and then introduce the papers in this Special Issue.

Research on High-Performance Networks

Over the years, several international cooperative research projects were conducted by IITIS-PAN together with French research laboratories where my former students were active. In particular, my former Turkish PhD student Prof. Tülin Atmaca of the Institut National des Télécommunications organized projects running from 2009 to 2014 with the support of CNRS (France) on energy savings [75, 92, 93] on integrated access networks with Prof. Czachòrski [102].

In the period 1996–2007, they ran three projects on modelling the congestion control schemes in high-speed networks, on the performance of traffic admission and differentiated quality of serve on multi-service networks, and on load balancing based on different traffic characteristics in optical networks. In the period 1998–2000, they received a Polonium Project from Poland to study the performance modeling of congestion control in high-speed networks [8, 116, 117].

In addition, in the years 1996–1998, Prof. Atmaca and Czachòrski developed a cooperative network including France, Poland and Slovakia with the help of Dr Pavol Podharadsky of the Technical University of Bratislava, Prof. Martin Klimo of the University of Zilima in Slovakia together with IITIS-PAN and INT in Evry, France, focusing on the performance modelling of very fast networks.

Diffusion Approximations

At the time when this Franco-Polish collaboration started, one of the significant areas of work in my team in France was the development of new methods for the approximate analysis of computer systems, networks and queues, based on Diffusion Approximations [3, 57, 94] which were also discussed in books and monographs that we initially published in those years [91, 95, 96].

Andrzej Duda, who had worked with Tadeusz Czachorski in Gliwice for his Master's thesis then joined my group at Orsay to prepare a PhD thesis, and one of the topics that I suggested to him was the matter of diffusion approximations, to which he made several noted contributions to transient analysis of queueing systems under my research supervision [47, 48, 134].

Diffusion approximations also became a favourite research topic for Prof. Czachorski who continues actively in this direction to this day, for instance, in [23, 33, 37], and also [28, 31, 32, 34–36], among many other papers, very often in close collaboration with my former PhD student Dr Ferhan Pekergin of the University of Paris-Nord, with my former PhD students Prof. Tülin Atmaca [8] and Jean-Michel Fourneau [52]. Professor Czachorski's team has also developed related work on the performance of high-speed data networks [27, 41, 131].

In direct relation to my earlier work on average packet travel times in wireless networks [2, 65, 67], Prof Czachorski (again with Dr Ferhan Pekergin) studied analogous models to compute the probability distribution of the travel times in sensor networks [29, 30].

Yet another area of application of the diffusion models that I developed was the block loss analysis of ATM networks [88] that served as the basis for admission control for "calls" or connections [89, 90, 121]. Similar work followed between IITIS-PAN researchers and my former students [8].

Distributed Systems and Databases

The initial contacts with Poland had also resulted in contacts with other researchers, notably Professors Jacek Blazewicz and Roman Slowinski and their team who were interested in topics related to scheduling of tasks, which is relevant to many areas in computer science including system performance evaluation [14, 141].

Among them was Dr Wojciech Cellary from Poznan, with whom we started a steady collaboration which first resulted in a joint book on Distributed Databases that included Dr J. Morzy of Poznan Technical University [18]. On my side, this work was initially motivated by my earlier work in the control and information sharing in concurrent computation [97], and my interest in the performance of distributed algorithms which can be slowed down by the data that they share and the need to synchronize parallel computations [10, 21, 22].

Some of these questions were also pursued by my Polish PhD student Andrzej Duda together with my other former PhD students such as Guy Bernard, Yoram Haddad and Gilbert Harrus at Orsay with regard to the issue of time in distributed systems [12, 51].

The 1980s were also the years when we also conducted other work on the performance of multiprocessor systems

[60] where the objective was to determine the speedup that could be obtained as a function of the number of available processors and other architectural aspects such as the interconnection networks used to link the processors to the memory system. However, our work also addressed the intrinsic limitations of the parallelism within the programs themselves which we had studied with my student Zhen Liu [87] who years later was the Director of the Nokia Laboratory. Similar problems were then also studied by my Polish student Andrzej Duda and Professor Czachorski [49, 50].

Database Research

I believe it was in 1986, when Professor Cellary spent a year in my laboratory at Orsay, and taught a course to replace my absence that year as a Ministerial Advisor for Science and Technology, that Wojciech built important links with members of my team.

During that time, a new and very productive collaboration was launched on Database Theory and design with my former doctoral student Geneviève Jomier, including the work in [16, 17, 19, 110], and this collaboration has lasted until a fairly recent period prior to Professor Jomier's unfortunate and untimely death.

System Reliability and Checkpoints

Interestingly enough, the reliability of the execution of programs is crucial to multiprocessing, where very long running programs for high-performance computing (HPC) applications should be able to recover quickly from any hardware or system failures to avoid having to execute the whole program from its start. Similarly, this is also the case for databases where an "audit trail" records all the updates that have been made in the database, and when a failure occurs one should be able to avoid having to re-run the whole "history" or "audit trail" of the database, and re-start it from some recent state.

In both cases, the key technique that is used is based on checkpoints which are periodically created in these long-running programs to be able to re-establish the database or program state with low overhead after a failure. In both cases, the issue is to select an inter-checkpoint interval which minimizes system overhead. In recent work, this overhead needs to include the cost of energy.

Thus, we pioneered research in this area starting in the 1970s [58, 77, 82], and this also generated ideas for work for our Polish students and colleagues [45, 46].

We can also cite some further joint work with American colleagues regarding checkpoints in large-scale distributed systems [79, 80, 135], and further recent work being pursued in the current SDK4ED project with colleagues from Greece [130]and now Poland.

Energy Savings in ICT and Energy Packet Networks

The large amount of energy consumption by Information and Communication Technologies (ICT) [75] has resulted in the study of computer and communication systems that use renewable energy, e.g. photovoltaic [119], ambient electromagnetics [1], vibrations [20, 115] and piezo-electricity [109]. Their effectiveness depends on intermittent energy sources, converters, and energy storage to achieve steady energy flow to devices when the sources' supply of energy is interrupted. The quality of service (QoS) and energy consumption of sensor systems, the IoT [112], Cloud Computing [11], servers [84], and embedded systems [118] are of great interest for a "greener" ICT [106].

Wireless systems [39, 81] require much research to maximize throughput maximization and minimize transmission delay with energy harvesting [108, 127, 144]. Energy cooperation can also use wireless energy exchange among devices [105]. Multiple access with intermittent data and energy [143], energy cooperation [104]. In [5], online power scheduling and delay minimization [6], transmitted data maximization [38], and throughput maximization are also studied [114, 136]. Energy savings in wired networks include measurements [98] and simulations [126].

The Energy Packet Network (EPN) model is a mathematical abstraction for interconnected processing units or data transmission nodes that receive random flows of energy and data or jobs [68, 69] based on G-Networks [54, 55, 63, 107, 120]. It has been used for the QoS analysis of systems that operate with intermittent sources of energy [76]. A related concept has also been suggested in work that originated in Japan [132, 133]. In [71], service times for forwarding packets are neglected and arrivals of EPs cause the forwarding of data packets [111]. Multihop EPN models are studied in [72] to represent the backbone of a mobile network, and related models can be found in [44]. In [145], a utility function including wasted power and the average delay of jobs is used to optimize an EPN.

Thus, in the closely paper by Jean-Michel Fourneau from the DAVID/CNRS Laboratory of the University of Versailles Saint-Quentin on "Energy Packet Networks with Interrupted Poisson Energy Arrivals and Job Balancing" that is included in this Special Issue [53], the flow of EPs is represented by an interrupted Poisson process and the job flow is balanced among servers.

High-Impact Conference Proceedings

As part of this Franco-Polish collaboration, we should mention the series of annual conferences known as ISCIS or *International Symposium on Computer and Information Sciences* that I started in Ankara (Turkey) in 1986 and which were held regularly since then. Many of their Proceedings have been published in the Springer Lecture Notes Series, some others by the IEEE and other academic publishers such as Nova Science Press, and they have had great measurable international impact. As examples of this impact, officially stated by Springer:

- The Proceedings of ISCIS 2010 [86] received over 51,600 downloads shared among some 40 papers, or over 1200 downloads on average per paper, with similar results for [85].
- The Proceedings of ISCIS 2012 published in 2013 [83] received over 39,927 downloads, or roughly 1000 per paper on average.
- The Proceedings of ISCIS 2015 [4] received 20,477 downloads, or on average roughly 500 downloads per paper.

Of course, the downloads are cumulative over time and the older proceedings have typically accumulated more downloads.

Thus, through ongoing collaborations, often with my former students and team members, also with their Polish co-authors, many researchers from Poland have published at these conferences. At the same time, French researchers have also expanded their interactions and the variety of problems that they have worked on, thanks to the contributions of Polish researchers. They have also benefited from these conferences to establish additional international contacts due to the presence of other researchers from Europe, North America and other regions.

In addition, in 2014 [26], we proposed to take the 29th ISCIS Symposium to Poland for the first time, and with IITIS-PAN it was held in Krakow very successfully. The Springer Proceedings have obtained over 28,000 downloads since its publication or some 700 on average per paper.

This was repeated with the 31st ISCIS in Krakow which was a phenomenal success. Indeed, the papers in this conference's Proceedings [24] have to this day been downloaded 122,965 times according to Springer Nature, the conference's publisher, with some 2000 downloads on average per paper.

The experience was repeated in 2018, jointly with the IFIP World Computing Conference (WCC). The ISCIS 2018 Springer Proceedings [25], which were *not* published in Open Access due to the rules of the 2018 IFIP WCC, have nevertheless attracted over 8,827 paid downloads or over 200 per paper on average.

Let us also mention the 2018 ISCIS Cyber-Security Conference [74] that I organized, also published by Springer in Open Access mode, which has already received 48,694 downloads for a total of less than 20 papers.

Current Developments: Cybersecurity of the IoT, Dependability and Energy Savings

As we celebrate a Franco-Polish Collaboration that is focused on the Modelling and Performance Evaluation of Computer Systems and Networks that has continued uninterruptedly since the 1980s for more than 30 years, let me outline some of its current highlights.

In 2016, with my close collaborators at the Informatics and Telematics Institute of CERTH in Thessaloniki, we submitted a proposal for a 5M Euro Research and Innovation Action, the Project SerIoT, to the European Commission with the understanding that I would coordinate the project. The notification of success reached us after the UK had voted in favour of Brexit, and the UK government invoked Article 50 to leave the EU. With my collaborators, we then decided that the project should be housed in an institution that was clearly part of the EU, and the decision was taken to move it to the Institute of Theoretical and Applied Informatics (IITIS-PAN) in Gliwice, Poland, where I could coordinate it as a Professor and Foreign Fellow of the Polish Academy of Sciences.

Thus, IITIS-PAN is currently the only Institute of the Polish Academy of Sciences that is coordinating such a European Research and Innovation action.

The SerIoT project began its work in January of 2018, and started with our earlier research on using Machine Learning to dynamically enhance network security using Software Defined Networks (SDN) to implement network control functions [56]. SerIoT uses concepts from Self-Aware Networks [13, 40] and more specifically the Cognitive Packet Network routing algorithm [66, 139].

The aims, plans and first results of the project that relate to SerIoT's cognitive and secure SDN routing engine for the Internet of Things are outlined in several recent papers [42, 73, 78, 124, 125].

Also, as part of the EU Horizon 2020 Project SDK4ED which I transferred to IITIS-PAN, we study the enhancement of dependability in embedded software and have shown how checkpoints can be used in programs to guarantee their dependability at minimum cost in terms of program execution time and overhead [130]. We also study the energy consumption minimization in software and in [100], we show how to allocate the flow of energy to energy store of servers

which operate with intermittent energy so as to minimize the average response time of jobs, and how the judicious offloading of a job from a given server to another can be used to minimize the job response time. In [99], we prove the intriguing result that when the number of jobs that can be processed by one EP has a geometric distribution, then to minimize the average response time of jobs, the share of jobs that are assigned to a given server must be identical to the share of energy that is assigned to that server's energy store, and we obtain the optimum value explicitly.

Currently, a total of five senior researchers, two research students, and two administrative staff members, are fully involved in these two research actions funded by the European Commission.

Content of this Special Issue

This Special Issue which is based on selected papers from the Conference celebrating *French–Polish* scientific cooperation on *Mathematical Modelling of Computer Systems, Networks and Bioinformatics* that was held in Paris during October 14–15, 2019.

Its full program can be found at https://projekty.iitis.pl/agenda-3, and includes papers that are grouped in several related sub-areas.

The first set of papers discuss different aspects in computer system and network modelling, and include four papers from Poland, one from France, a joint Franco-Polish paper, and two papers from our long-term visitors and collaborators from Greece and Italy. Thus, our work on G-Networks [62] leads to the results in [53], when combined with our development of the Energy Packet Network model [70] to achieve job balance and lower energy consumption in data centers. The next paper [101] addresses similar issues using measurements and analytical models.

Then in [103], the performance of massive repositories that are needed to support Smart Cities is discussed. The work in [43] uses diffusion approximations, which have been a steady theme in our collaborations [59], and the following paper [113] develops certain analytical computational methods for diffusion approximation models. The work discussed in [9] models a control issue that is specific to optical networks, while the research discussed in [7] examines how networked systems can support the specific needs of smart automated vehicles.

The next two papers focus on data science, and in [123] networked data are used to create alerts regarding international risks, while [122] describes a general purpose data analysis tool.

The third set of papers concern neuronal models, and the work in [129] uses the Random Neural Network that was introduced in [61, 64] to develop hierarchical neural networks that are designed to conduct cognitive routing that directs traffic in wireless networks that are subject to wireless radio interference and overload and loss effects, using ideas similar to those that are developed in earlier work [15, 137–139].

On the other hand, the work in [128] develops a combination of analytically based methods and simulation techniques to accelerate the discrete event simulation of very large neural networks. Finally, the last paper [146] studies inherent physical properties of networks of blood vessels, such as the relative diameters of interconnected vessels, that appear to optimize blood flow.

1. [53] Jean-Michel Fourneau "Modeling green data-centers and jobs balancing with Energy Packet Networks and interrupted Poisson energy arrivals".
2. [101] Dipak Ghosal, Goldwayne Yeh, Sambit Shukla, Matthew Farrens and Jian Wu. Model Driven "Joint Optimization of Power and Latency Guarantee in Datacenter Applications".
3. [103] Michal Gorawski and Krzysztof Grochla "Performance tests of Smart City IoT data repositories for universal linear infrastructure data and graph databases".
4. [43] Adam Domanski, Joanna Domanska, Tadeusz Czachorski, Jerzy Klamka, Jakub Szygua and Dariusz Marek "Diffusion approximation model of TCP NewReno congestion control mechanism".
5. [113] Dzmitry Kopats and Mikhail Matalytski "About diffusion approximation of open queueing network with limited number of customer and time-dependent service parameters".
6. [9] Tülin Atmaca, Artur Rataj and Amira Kamli "Analysis of a frequency response of a noisy optical network for its self-adaptation".
7. [7] Leonardo Arcari, Marco Gribaudo, Gianluca Palermo and Giuseppe Serazzi "Performance-driven Analysis for an Adaptive Car Navigation Service on HPC Systems".
8. [123] Xiang Niu, Gyorgy Korniss and Boleslaw Szymanski "Supervised learning of the global risk network activation from media event reports".
9. [122] Karol Niedzielewski, Maciej Marchwiany, Radoslaw Piliszek, Marek Michalewicz and Witold Rudnicki "Multidimensional feature selection and high performance ParalleX".
10. [129] Artur Rataj "Random neural networks with hierarchical committees for improved routing in wireless mesh networks with interference".
11. [128] Tien Cuong Phi, Alexandre Muzy and Patricia Reynaud-Bouret "Event-scheduling algorithms with Kalikov decomposition for simulating potentially infinite neuronal networks".

12. [146] Jakub Zielinski and Jedrzej Nowosielski "Finet's law as a special case of the generalised Murray's law".

This set of papers comprising eight papers from Poland, three from France, two from the USA, and one from Italy, illustrates the wealth of topics and exchanges from this international scientific collaboration.

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