

# Communications in Computer and Information Science

1151

*Commenced Publication in 2007*

Founding and Former Series Editors:

Phoebe Chen, Alfredo Cuzzocrea, Xiaoyong Du, Orhun Kara, Ting Liu,  
Krishna M. Sivalingam, Dominik Ślęzak, Takashi Washio, Xiaokang Yang,  
and Junsong Yuan

## Editorial Board Members

Simone Diniz Junqueira Barbosa 

*Pontifical Catholic University of Rio de Janeiro (PUC-Rio),  
Rio de Janeiro, Brazil*

Joaquim Filipe 

*Polytechnic Institute of Setúbal, Setúbal, Portugal*

Ashish Ghosh

*Indian Statistical Institute, Kolkata, India*

Igor Kotenko 

*St. Petersburg Institute for Informatics and Automation of the Russian  
Academy of Sciences, St. Petersburg, Russia*

Lizhu Zhou

*Tsinghua University, Beijing, China*


More information about this series at <http://www.springer.com/series/7899>


Moisés Torres · Jaime Klapp (Eds.)

# Supercomputing

10th International Conference on Supercomputing in Mexico, ISUM 2019  
Monterrey, Mexico, March 25–29, 2019  
Revised Selected Papers

*Editors*

Moisés Torres   
Sociedad Mexicana de Supercomputo  
Guadalajara, Jalisco, Mexico

Jaime Klapp   
Instituto Nacional de Investigaciones  
Nucleares  
La Marquesa, Estado de México, Mexico

ISSN 1865-0929 ISSN 1865-0937 (electronic)  
Communications in Computer and Information Science  
ISBN 978-3-030-38042-7 ISBN 978-3-030-38043-4 (eBook)  
<https://doi.org/10.1007/978-3-030-38043-4>

© Springer Nature Switzerland AG 2019

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG  
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

## Preface

High Performance Computing (HPC) or Supercomputing have the power to contribute in an important way to the research and development of a country and to improve and reform many industrial sectors. Researchers at universities and engineers in diverse industries, have come to depend on the power of these machines to compute high volumes of data for finding the results they are looking for. Complex calculations in many cases require high volumes of data that would have taken hours, days, and sometimes weeks or months to process two to three decades ago. But now a days with the processing power that HPC machines manage, we are able to move faster with our results to save time, money, and often sometimes lives. On the other hand, we can now perform numerical simulations with a much higher resolution that is translated into producing results which better reproduce the physical world in which we live.

As an example of an HPC initiative that could boost the development of an industry in a country, we mention that the Mexican government and the European Union (EU) decided to collaborate to improve their energy industries, which provided an opportunity for EU HPC researchers to team up with Mexican colleagues. The aim? To provide solutions for the oil and gas industry, improve wind energy performance, and solve issues of combustion efficiency for transportation systems. Recently launched in Barcelona (June 2019), ENERXICO, a new project jointly funded by the EU and the Mexican government, brought together 15 institutions in an academic-industry collaboration to solve real-world engineering problems. It focused on scaling in wind energy, oil/gas exploration and reservoir modeling, and biofuels for transportation. In parallel, to power these applications, the project will work on achieving scalable, energy-efficient simulations for the exascale era. The project is led by the Instituto Nacional de Investigaciones Nucleares of México (ININ) and the Barcelona Supercomputer Centre of Spain (BSC). The other institutions that collaborated in the project are: Petróleos Mexicanos (PEMEX-PEP), Universidad Autónoma Metropolitana, Universidad Nacional Autónoma de México, Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, Instituto Mexicano del Petróleo, Instituto Politécnico Nacional, Technische Universität München, Université Grenoble Alpes, Centro de Investigaciones Energéticas, Medioambientales y Tecnologías, Repsol, Iberdrola, Bull Atos, and Universitat Politècnica de Valencia. We hope that following the ENERXICO project, new HPC large scale initiatives will be carried out in Mexico.

This 10th International Supercomputing Conference in Mexico fosters the continuous growth of HPC in Mexico and Latin America, gathering the supercomputing communities to share their latest research works.

It is worth noting that Mexico has significant experience in the uses of supercomputers, which began in 1991, when UNAM installed a Cray YMP. Afterwards, Mexico appeared in the Top 500 supercomputing list several times: the case of the oil industry (Top 83, Top 84, and Top 85 in the list of November 2003). A few years later, UNAM and UAM placed computers in places 126 (2006) and 225 (2008), respectively. Other

outstanding projects in Mexico are the National Laboratory for High Performance Computing in Mexico City (UNAM-UAM-CINVESTAV), the National Supercomputing Center of San Luis Potosi within the Instituto Potosino de Investigación Científica y Tecnológica (IPICYT), the Grids National Laboratory, the National Supercomputing Laboratory of the Southeast (LNS) from the Benemérita Universidad Autónoma de Puebla, and ABACUS CINVESTAV, which placed its supercomputer in the 255 place of the top 500 list of June 2015. In addition to these laboratories, a recent new supercomputer center was inaugurated at the University of Guadalajara, Centro de Análisis de Datos y Supercómputo (CADS), and the University Autonomous of the State of Mexico (UAEMEX) will be opening a center in the next year. Although we have a platform and experience in supercomputing, these supercomputing resources are not enough to conduct research and development for a country like Mexico. The joint efforts by institutions, organizations, and government continue to examine the direction and need in academia, government, society, and industry of computer power to advance research and development.

With an effort to continue to evolve in the uses of supercomputing and of these powerful machines in research and development in Mexico and Latin America, the International Supercomputing Conference in Mexico (ISUM) was founded by a group of researchers, supercomputing directors, IT directors, and technologists representing the largest research institutions, along with the support of the largest technology vendors in Mexico. This conference was established to provide a space for researchers and technologists to present their research works related to HPC. Building on the experience of the previous 9 editions, this 10th edition of ISUM was held in the progressive and industrial city of Monterrey, Nuevo Leon, Mexico, where more than 1,205 attendees had the opportunity to hear 5 international keynote speakers, 16 national and international speakers, 10 thematic tracks, and more than 60 research presentations. The conference covered themes in HPC architecture, networks, system software, algorithmic techniques, modeling and system tools, clouds, distributed computing, big data, data analytics, visualization and storage, applications for science and engineering, and emerging technologies. The thematic tracks included, Smart-Cities, Artificial Intelligence, Cybersecurity, Energy, Supercomputer Infrastructure, Women in STEM, Supercomputer Projects in Mexico, Supercomputing in Latin America, Biotechnology, and Supercomputing in Nuevo Leon, Monterrey. There were five workshops offered in various areas of supercomputing conducted by an international group of instructors. In addition, the conference had 2 plenary round tables and 10 round tables in the thematic tracks where important issues related to supercomputing were discussed; themes like strengthening graduate programs in supercomputing in Mexico, creating national and international project opportunities in supercomputing, and fostering the uses of supercomputing in industry for the development of Mexico and Latin America in areas such as artificial intelligence, biotechnology, smartcities, etc. These round tables gathered experts in the respective areas representing Mexico, Europe, and Latin America and included academia, industry, and government.

The central part of ISUM is the presentation of the latest research work conducted primarily but not limited to Mexico and Latin America. This book presents the selected works from more than 70 works presented at ISUM 2019. Each work was reviewed by

three expert reviewers from an international group of experts in the respective area. These works are divided into five parts that include, Part I: Applications; Part II: Algorithm Techniques; Part III: HPC Architecture; Part IV: Parallel Computing; and Part V: HPC Modelling. Each section presents a series of works that you will find instrumental and enhancing to your repertoire of knowledge in the respective areas of study.

The book is aimed towards senior undergraduate and graduate students, as well as scientists in the fields of HPC, computer sciences, physics, biology, mathematics, engineering, and chemistry, who have an interest in the solution of a large variety of problems that make use of supercomputers. The material included in this book is adequate for both teaching and research.

The editors are grateful to the institutions and people who made possible ISUM 2019 through their support: Cesar Díaz Torrejón, Universidad Abierta y a Distancia de México (UnADM); Luis Díaz Sánchez, Universidad Autónoma del Estado de México (UAEMEX); Luis Gutiérrez Díaz de León, Universidad de Guadalajara; Felipe Bracho Carpizo y Fabián Romo, Universidad Autónoma de México (UNAM); Raúl Rivera, Centro de Investigación Científica y de Educación Superior de Ensenada (CISESE); Carlos Casasús López Hermosa, Corporación Universitaria para el Desarrollo de internet (CUDI); Salma Leticia Jalife Villalón, Secretaria de Comunicaciones y Transporte (SCT); and Moisés Torres Martínez, Sociedad Mexicana de Supercómputo (SOMEXSU A.C.) Universidad Abierta y a Distancia de México, and Red Mexicana de Supercómputo (REDMEXSU) Consejo Técnico Académico (CTA). We give special recognition to our corporate sponsors, without whom this event would not have been possible. Special recognition to ATOS, IBM/Sinergia Sys, DELL, Intel, Totalplay Empresarial, Fujitsu, IPICYT-CNS, Global Hitss, SparkCognition, Mellanox, Lenovo, and ITEXICO.

The following individuals were instrumental in leading the evaluation of these works: Juan Manuel Ramírez Alcaraz, Alfredo Cristóbal Salas, Andrei Tchernykh, Cesar Díaz Torrejón, Erwin Martin, Enrique Varela, Jaime Klapp, Liliana Barbosa Santillán, Luis Díaz Sánchez, Luis Gutiérrez Díaz de León, Moises Torres Martínez, Manuel Aguilar Cornejo, Rene Luna, Salvador Castañeda, and Sergio Nemeschnow. We thank them for the time spent in coordinating the evaluation process of these research works.

We give special thanks to the ISUM national and local committees, and Universidad Autónoma de Nuevo León for all their support in making this event possible. We give special thanks to Veronica Lizette Robles Dueñas, Marlene Ilse Martinez Rodriguez, Claudia Karina Casillas Godínez, Angie Fernández Olimón, Adriana Margarita Jimenez Cortez, and Araceli Gutierrez Campuzano for all their support in organizing all the logistics of this successful edition of ISUM.

The thematic track on “HPC Energy Applications and the ENERXICO Project” as well as the production of this book received funding from the ENERXICO project under the European Union’s Horizon 2020 Programme, grant agreement n° 828947, and from the Mexican Department of Energy, CONACYT-SENER Hidrocarburos

grant agreement n° B-S-69926, and from the Ibero-American Programme for the Development of Science and Technology (CYTED) under Project 516RT0512, CONICYT (Chile).

In conclusion we thank all the institutions who have supported this event throughout these 10 editions, especially this 10th anniversary of ISUM: BUAP LNS-SURESTE, UdeG, UCol, UNISON, ININ, CUDI, IPN, UAM, UNAM, CICESE, CIMAT-Merida, UAEMEX, CNS-IPICYT, ABACUS-CINVESTAV, CONACYT, SOMEXSU A.C., and REDMEXSU.

October 2019

Moisés Torres  
Jaime Klapp



# Organization

Sociedad Mexicana de Supercómputo A.C. (SOMEXSU A.C.) and Red Mexicana de Supercómputo (REDMEXSU).

## Organizing Committee

Moisés Torres Martínez	SOMEXSU A.C. and Universidad de Guadalajara (UDG), Mexico
Jaime Klapp	Instituto Nacional de Investigaciones Nucleares (ININ), Mexico
César Carlos Díaz Torrejón	SOMEXSU A.C. and Universidad Abierta y a Distancia de Mexico (UnADM), Mexico
Salvador Castañeda Ávila	Centro de Investigación Científica y de Educación Superior de Ensenada, Baja California (CICESE), Mexico
Luis Enrique Díaz Sánchez	SOMEXSU A.C. and Universidad Autónoma del Estado de México (UAEMEX), Mexico
Luis Alberto Gutiérrez Díaz de León	Universidad de Guadalajara (UDG), Mexico
Raúl Rivera Rodríguez	Centro de Investigación Científica y de Educación Superior de Ensenada, Baja California (CICESE), Mexico
Andrei Tchernykh	Centro de Investigación Científica y de Educación Superior de Ensenada, Baja California (CICESE), Mexico
Isidoro Gitler	Laboratorio de Matemática Aplicada y Cómputo de Alto Rendimiento (CINVESTAV-ABACUS), Mexico
René Luna García	Instituto Politécnico Nacional (IPN), Mexico
Manuel Aguilar Cornejo	Universidad Autónoma Metropolitana (UAM), Mexico
Juan Manuel Ramírez Alcaraz	Universidad de Colima (UCOL), Mexico
Jesús Cruz Gúzman	Universidad Nacional Autónoma de México (UNAM), Mexico
Alfredo Santillán González	Universidad Nacional Autónoma de México (UNAM), Mexico
Raúl Hazas Izquierdo	Universidad de Sonora (UNISON), Mexico
Erwin Martín Panameño	Benemérita Universidad Autónoma de Puebla (BUAP), Mexico
Fabián Romo	Universidad Nacional Autónoma de México (UNAM), Mexico

Juan Manuel Ramírez	Universidad de Colima (UCOL), Mexico
Alcaraz	
Alfredo Cristóbal	Universidad Veracruzana (UV), Mexico
Liliana Barbosa	Universidad de Guadalajara (UdeG), Mexico
Carlos Franco Rebodera	Universidad de Guadalajara (UdeG), Mexico
Eduardo de la Fuente	Universidad de Guadalajara (UdeG), Mexico
Isabel Pedraza	Benemérita Universidad de Puebla (BUAP), Mexico

## Program Committee

### Members

Andrés Ávila, Chile	Ricardo Farias, Brazil
Alejandro Avilés, Mexico	Alejandro Flores-Méndez, Mexico
Javier R. Balderrama, France	Ruslan Gabbasov, Mexico
Carlos J. Barrios, Colombia	Verónica Gil Costa, Argentina
Lola Bautista, Colombia	Isidoro Gitler, Mexico
Carlos Bederian, Argentina	Brice Goglin, France
Cristiana Bentes, Brazil	Antonio Gomes, Brazil
Cristina Boeres, Brazil	José L. Gordillo, Mexico
Rossana Bonasia, Mexico	Benjamín Hernández, USA
Francisco Brasileiro, Brazil	Gonzalo Hernández, Chile
Carlos Buil Aranda, Chile	Tiberio Hernández, Colombia
Victor Calo, Saudi Arabia	Salma Jalife, Mexico
Néstor Calvo, Argentina	Jaime Klapp, Mexico
Luis Fernando Castillo, Colombia	Alejandro Kolton, Argentina
Marcio Castro, Brazil	Roberto León, Chile
Harold Castro, Colombia	Francisco Luna, Spain
Gerson Cavalheiro, Brazil	Rafael Mayo, Spain
Marcia Cera, Brazil	Ricardo Medel, Argentina
Andrea Charao, Brazil	Wagner Meira Jr., Brazil
Esteban Clua, Brazil	Alba Melo, Brazil
Daniel Cordeiro, Brazil	Esteban Menezes, Costa Rica
Álvaro Coutinho, Brazil	Renato Miceli, Brazil
Fernando Crespo, Chile	Pablo Mininni, Argentina
Marcela Cruchaga, Chile	David Monge, Argentina
Jesús Cruz, Mexico	Sergio Nesmachnow, Uruguay
Gregoire Danoy, Luxembourg	Luis Nuñez, Colombia
Alvaro de la Ossa, Costa Rica	Julio Paciello, Paraguay
Claudio Delrieux, Argentina	Elina Pacini, Argentina
César Díaz, Colombia	Jairo Panetta, Brazil
César Díaz, Mexico	Johnatan Pecero, Mexico
Gilberto Díaz, Venezuela	Gabriel Pedraza, Colombia
Bernabé Dorronsoro, France	Guilherme Peretti Pezzi, Italy
Nicolás Erdody, New Zealand	Jorge Pérez, Belgique
Pablo Ezzatti, Uruguay	Carlos Piedrahita, Colombia

Laercio Pilla, Brazil  
 Carlos Hernán, France  
 Javier Príncipe, Spain  
 Marcela Printista, Argentina  
 Juan Manuel Ramírez Alcaraz, Mexico  
 Raúl Ramos Pollan, Mexico  
 Vinod Rebello, Brazil  
 Olivier Richard, France  
 Genghis Ríos, Peru  
 Robinson Rivas, Venezuela  
 Ascanio Rojas, Venezuela  
 Isaac Rudomin, Spain  
 Alfredo Cristóbal Salas, Mexico  
 Alfonso Sales, Brazil  
 Liria Sato, Brazil  
 Lucas Schnorr, France  
 Hermes Senger, Brazil

Alejandro Soba, Argentina  
 Luiz Angelo Steffenel, France  
 Mario Storti, Argentina  
 Andrei Tchernykh, Mexico  
 Fernando Tinetti, Argentina  
 Patricia Tissera, Argentina  
 Claudio Torres, Chile  
 Moisés Torres, Mexico  
 Tram Truong Huu, Singapore  
 Manuel Ujaldón, Spain  
 Grabiél Usera, Uruguay  
 Carlos A. Varela, USA  
 Mariano Vasquez, Spain  
 José Luis Vazquez-Poletti, Spain  
 Pedro Velho, Brazil  
 Jesús Verduzco, Mexico  
 Nicolás Wolovick, Argentina

## Editorial Committee

### Chairs

Moisés Torres Martínez	SOMEXSU A.C. and Universidad de Guadalajara (UDG), Mexico
Jaime Klapp	Instituto Nacional de Ciencias Nucleares (ININ), Mexico

### Sponsoring Institutions

- Sociedad Mexicana de Supercómputo (SOMEXSU A.C.)
- Red Mexicana de Supercómputo (REDMEXSU)
- Consejo Nacional de Ciencia y Tecnología (Conacyt)
- Instituto Nacional de Investigaciones Nucleares (ININ)
- Universidad de Guadalajara
- Universidad Autónoma de Nuevo León
- Nuevo León 4.0
- Laboratorio de Matemática Aplicada y Computo de Alto Rendimiento (Abacus) of the Centro de Investigación y de Estudios Avanzados of the Instituto Politécnico Nacional
- ENERXICO Project: European Union Horizon 2020 Programme, Grant Agreement No. 828947, and the Mexican CONACYT-SENER-Hidrocarburos, Grant Agreement No. B-S-69926
- Ibero-American Programme for the Development of Science and Technology (CYTED) under Project 516RT0512, CONICYT

# Acknowledgments

The production of this book has been sponsored by the Sociedad Mexicana de Supercomputo (SOMEXSU A.C.), Red Mexicana de Supercomputo (REDMEXSU), Consejo Nacional de Ciencia y Tecnología (Conacyt), Instituto Nacional de Investigaciones Nucleares, Universidad de Guadalajara, Universidad Abierta y a Distancia de México (UnADM), Universidad Autónoma de Nuevo León, Nuevo León 4.0, Centro de Investigación y de Estudios Avanzados of the Instituto Politécnico Nacional (Cinvestav-Abacus), Universidad Nacional Autónoma de México, CYTED Project No. 516RT0512 (CONICYT, Chile), and the ENERXICO project (through the European Union Horizon 2020 Programme, Grant Agreement No. 828947, and the Mexican CONACYT-SENER-Hidrocarburos Grant Agreement No. B-S-69926).

# Contents

## Applications

Generation and Classification of Energy Load Curves Using a Distributed MapReduce Approach . . . . .	3
<i>Santiago Garabedian, Rodrigo Porteiro, and Sergio Nesmachnow</i>	
Spectrum Sample Calculation of Discrete, Aperiodic and Finite Signals Using the Discrete Time Fourier Transform (DTFT) . . . . .	18
<i>Julio Cesar Taboada-Echave, Modesto Medina-Melendrez, and Leopoldo Noel Gaxiola-Sánchez</i>	
Software Defined Data Center for High Performance Computing Applications. . . . .	27
<i>J. E. Lozano-Rizk, J. I. Nieto-Hipolito, R. Rivera-Rodriguez, M. A. Cosio-Leon, M. Vazquez-Briseno, J. C. Chimal-Eguia, V. Rico-Rodriguez, and E. Martinez-Martinez</i>	
ETL Processing in Business Intelligence Projects for Public Transportation Systems . . . . .	42
<i>Alfredo Cristobal-Salas, Andrei Tchernykh, Sergio Nesmachnow, Ceila-Yasmin García-Morales, Bardo Santiago-Vicente, José-Eduardo Herrera-Vargas, Carolina Solís-Maldonado, and Raúl-Alejandro Luna-Sánchez</i>	
Molecular Rotors in Viscous Fluids: A Numerical Analysis Aid by GPU Computing. . . . .	51
<i>Daniel Gutiérrez-Garibay and Humberto Híjar</i>	
SPH Numerical Simulations of the Deformation of a Liquid Surface in Two Dimensions . . . . .	63
<i>Cristian Cáliz-Reyes, Laura A. Ibarra-Bracamontes, Rosanna Bonasia, and Gonzalo Viramontes-Gamboa</i>	
SiO <sub>2</sub> Electronic Structure in Gas Giants' Planetary Cores: A Density Functional Theory Approach . . . . .	76
<i>J. M. Ramírez-Velásquez and Joshua M. Salazar</i>	
Three Body Problem Applied to the Helium Atom System: The Independent Electron Approximation (IEA) . . . . .	86
<i>J. M. Ramírez-Velásquez and Jennifer A. Sanchez</i>	

Solution of Schrödinger Equation Not Implementing Conventional  
Separation of Variables: Using the Trial and Error Brute Force  
Permutation Method . . . . . 96  
*J. M. Ramírez-Velásquez and Ismael Villegas*

Lagrangian Approach for the Study of Heat Transfer in a Nuclear Reactor  
Core Using the SPH Methodology . . . . . 108  
*F. Pahuamba-Valdez, E. Mayoral-Villa, C. E. Alvarado-Rodríguez,  
J. Klapp, A. M. Gómez-Torres, and E. Del Valle-Gallegos*

**Algorithm Techniques**

Public Transportation System Real-Time Re-organization Due to Civil  
Protection Events . . . . . 127  
*Alfredo Cristóbal-Salas, Andrei Tchernykh, Sergio Nesmachnow,  
Bardo Santiago-Vicente, Raúl Alejandro Luna-Sánchez,  
and Carolina Solis-Maldonado*

Multi-objective Evolutive Multi-thread Path-Planning Algorithm  
Considering Real-Time Extreme Weather Events. . . . . 137  
*Alfredo Cristóbal-Salas, Andrei Tchernykh, Sergio Nesmachnow,  
Bardo Santiago-Vicente, Raúl Alejandro Luna-Sánchez,  
and Carolina Solis-Maldonado*

Multi-objective Optimization of Vehicle Routing  
with Environmental Penalty . . . . . 147  
*Luis Bernardo Pulido-Gaytan, Andrei Tchernykh, Sergio Nesmachnow,  
Alfredo Cristóbal-Salas, Arutyun Avetisyan,  
Harold Enrique Castro Barrera, and Carlos Jaime Barrios Hernandez*

Algorithm for Removing Secondary Lines Blended with Balmer Lines  
in Synthetic Spectra of Massive Stars . . . . . 163  
*Celia R. Fierro-Santillán, Jaime Klapp, Leonardo Di G. Sigalotti,  
and Janos Zsargó*

**HPC Architecture**

Multi GPU Implementation to Accelerate the CFD Simulation of a 3D  
Turbo-Machinery Benchmark Using the RapidCFD Library . . . . . 173  
*Daniel Molinero, Sergio Galván, Jesús Pacheco, and Nicolás Herrera*

Cluster-UY: Collaborative Scientific High Performance Computing  
in Uruguay. . . . . 188  
*Sergio Nesmachnow and Santiago Iturriaga*

Demand Response and Ancillary Services for Supercomputing and Datacenters . . . . .	203
<i>Sergio Nesmachnow, Santiago Iturriaga, Jonathan Muraña, Sebastián Montes de Oca, Gonzalo Belcredi, Pablo Monzón, Pablo Belzarena, and Juan Bazerque</i>	
Evaluation of GPUSPH Code for Simulations of Fluid Injection Through Submerged Entry Nozzle . . . . .	218
<i>Ruslan Gabbasov, Jesús González-Trejo, César Augusto Real-Ramírez, Mario Martínez Molina, and Francisco Cervantes-de la Torre</i>	
Creating and Using Large Grids of Pre-calculated Model Atmospheres for Rapid Analysis of Stellar Spectra . . . . .	227
<i>Janos Zsargó, Celia Rosa Fierro-Santillán, Jaime Klapp, Anabel Arrieta, Lorena Arias, Jurij Mendoza Valencia, and Leonardo Di G. Sigalotti</i>	
Lagarto I RISC-V Multi-core: Research Challenges to Build and Integrate a Network-on-Chip . . . . .	237
<i>Neiel I. Leyva-Santes, Ivan Pérez, César A. Hernández-Calderón, Enrique Vallejo, Miquel Moretó, Ramón Bevide, Marco A. Ramírez-Salinas, and Luis A. Villa-Vargas</i>	
<b>Parallel Computing</b>	
Discretization of the Convection-Diffusion Equation Using Discrete Exterior Calculus . . . . .	251
<i>Marco A. Noguez, Salvador Botello, and Rafael Herrera</i>	
Parallel Computing for Processing Data from Intelligent Transportation Systems . . . . .	266
<i>Jonathan Denis, Renzo Massobrio, Sergio Nesmachnow, Alfredo Cristóbal, Andrei Tchernykh, and Esteban Meneses</i>	
Multiphase Flows Simulation with the Smoothed Particle Hydrodynamics Method . . . . .	282
<i>Carlos E. Alvarado-Rodríguez, Jaime Klapp, J. M. Domínguez, A. R. Uribe-Ramírez, J. J. Ramírez-Minguela, and M. Gómez-Gesteira</i>	
A Parallel Implementation for Solving the Fluid and Rigid Body Interaction . . . . .	302
<i>C. Samaniego, G. Houzeaux, and M. Vázquez</i>	
Parallel High-Performance Computing Algorithm to Generate FEM-Compliant Volumetric Mesh Representations of Biomolecules at Atomic Scale . . . . .	318
<i>Jorge López, Salvador Botello, Rafael Herrera, and Mauricio Carrillo-Tripp</i>	

**HPC Modelling**

A Simple Model of the Flow in the Steam Chamber in SAGD  
Oil Recovery ..... 337  
    *F. J. Higuera and A. Medina*

**Author Index** ..... 347