

IFORS



NEWS

International Federation of Operational Research Societies

FROM THE PRESIDENT

IFORS 2020 IS APPROACHING!

Grazia Speranza <grazia.speranza@unibs.it>

IFORS has organized from the very beginning just one conference every three years. Compared with other associations or scientific societies, the IFORS triennial conference is a rare event and, also for this reason, very special and precious. The first IFORS conference was held in Oxford (UK) in 1957 and, since then, with perfect regularity, the conferences moved from continent to continent, from Europe to North America, to Asia, to South America. For the first time an IFORS conference was held in Africa (Sandton, South Africa) in 2005 and for the first time in Australia (Melbourne) in 2011. IFORS has not chosen the locations for its conferences with the objective of maximizing the number of participants but rather to spread the locations over the world map, to rotate over the IFORS regional groupings: ALIO (Latin American Ibero societies), APORS (Asian Pacific societies), EURO (European and African societies), NORAM (North American societies). IFORS aims at reaching all parts of the world, to consolidate operations research where OR is well established and to promote OR where it is less established.



The last IFORS conference held in the APORS region took place in 1999 in China (Beijing). It was definitely time to move back to APORS. Seoul is ready to welcome the IFORS2020 participants in June. The deadline for the submission of abstracts expired at the end of January. More than 2000 abstracts were submitted with authors coming from 77 different countries. Numbers that exceeded the most optimistic forecast. A success!

At the beginning of February all the people involved in the organization of the IFORS2020 were excited for the large number of submitted abstracts. Unfortunately, in the meantime the coronavirus had become a serious problem in China, and out of China too, and we had to consider the possible impact of the emergency on the Chinese community and on the conference. We had to face a dilemma. Should we keep the planned deadline of February 28th for the early bird registration (after which the abstracts to be included in the program are finalized), work on the program and publish it as soon as possible so that the authors know when their talk is scheduled and book flights and accommodation? Or would it be better for our community to have a postponed deadline, to have more time for the coronavirus emergency to fade away, with a delay in the publication of the program? We decided for the second option in the hope that the delayed deadline will allow more time for the normalization of the situation and will allow the participants to make a more informed and stable traveling plan.

IFORS is close to that part of the community that has been affected by the coronavirus emergency and hopes the situation will return to a normal condition soon. I personally look forward to meeting all our Chinese friends in Seoul and to enjoying with them and with the whole community a scientifically and socially great IFORS2020. 🌍

WHAT'S INSIDE

From the President

- 1 IFORS 2020 is Approaching!

Editorial

- 2 From the Editor

OR IMPACT

- 3 Innovative Applications of Operations Research: Reducing Costs and Lead Times in Bio-manufacturing

OR for Development

- 6 An OR Application in Argentina: Optimizing Leaf Sweeping and Collection in the city of Trenque Lauquen

OR Tutorial

- 8 A brief tutorial on Gomory cuts

NEWS

- 10 AFROS: The ORMS hope of AFRICA

- 11 AIROyoung Group

CONFERENCES

- 12 NACA-ICOTA2019: Optimization, OR and Friendship in Hakodate, Japan
- 14 5th International Conference 2020, Numerical Analysis and Optimization, Oman
- 16 OPTIMA November 2019 in Santa Cruz, Chile: Celebrating Three Decades of OR Conference Tradition
- 17 OR Workshop in Poznan University of Technology, Poland, October 2019, Avenues of Modern OR
- 18 Risk analysis meets Bayesian network modelling in Wellington, Aotearoa, New Zealand, focusing on responsible and culturally appropriate decision-making, November 2019
- 20 An Avenue for OR in Indonesia: SIMANTAP November 2019 in Siantar
- 21 Young Business and Industrial Statisticians Discuss Advances in Data Science, Business Analytics and OR, at the Bosphorus in Istanbul, September 2019
- 22 11th ORSN International Conference at February 2020 Pokhara, Nepal, Operations Research and Sustainability

ARTICLES

- 23 What to look for at IFORS 2020 by Natasha Boland, Program Chair
- 24 OR Prize Finalists

BOOK REVIEW

- 26 Nonlinear Optimization

Editorial Box

FROM THE EDITOR

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The March 2020 issue is presented here with all the permanent sections and information on IFORS 2020. The presidential editorial message by Grazia states about the historical journey of IFORS from its establishment until now, the 22nd triennial conference of IFORS 2020, 21-26 June at Seoul. This issue describes about IFORS 2020 at Seoul by the program chair Natasha. The six finalists of 'OR for Development' is presented by Mario. A new OR Society, 'The African Federation of Operations Research Societies (AFROS)' is in existence and its details is presented in this issue. Also, an organization AIROyoung Group, a group of young OR practitioners is established in 2016, is described. Article on OR Impact "Innovative Applications of Operations Research: Reducing Costs and Lead Times in Bio-manufacturing" discusses on the impact of OR based approaches in increasing bio-manufacturing efficiencies. 'An OR Application in Argentina: Optimizing Leaf Sweeping and Collection in the city of Trenque Lauquen' in OR for Development section reveals the optimization of resources to make appropriate decision with a case of Argentina. The tutorial section presents "A brief tutorial on Gomory Cut" a programming session. Weber has compiled eight conferences on OR conducted throughout the world in Conference section. The Book "Non Linear Optimization" has been reviewed by Weber.



Wishing all for being safe from Corona Virus and hope to see you all in Seoul at IFORS 2020. 🌐

OR IMPACT

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INNOVATIVE APPLICATIONS OF OPERATIONS RESEARCH: REDUCING COSTS AND LEAD TIMES IN BIO-MANUFACTURING

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The biomanufacturing industry is growing rapidly and is projected to reach \$388 billion by 2024 but until recently has received little attention from OR. Pioneering studies, such as the ones described here, have shown there is huge potential for significant improvements in efficiency through innovative developments. An inter-disciplinary team of researchers from Merck Sharp and Dohme Animal Health (MSD AH) and Eindhoven University of Technology (TU/e) has been collaborating for almost four years to develop a portfolio of optimization models and decision support tools, which have resulted in an additional revenue of €50m. Their project is one of the first examples of the applications of OR in the biomanufacturing industry. Reference 1 gives technical details of the innovative work carried out.

Background

Recent advances in bio-manufacturing have made it possible to re-engineer living organisms, such as viruses and bacteria, and use them in the pharmaceutical drug manufacturing processes to generate active ingredients. The resulting active ingredients are highly complex and innovative compared to conventional drugs. For example, an active ingredient of a biopharmaceutical drug can consist of 25,000 atoms while a standard pain killer has only 21 atoms. Due to their difference in size and complexity, biopharmaceuticals are known as "next-generation drugs". To date, millions of patients have benefited from biopharmaceuticals to recover from cancer, diabetes and autoimmune disorders, among many others.



Biomanufacturing operations are highly complex and difficult to manage in practice. For example, the production process is cost/labour-intensive and involves high risks of failures. In addition, the industry is strictly regulated, i.e., the final product needs to abide by pre-determined requirements on batch quality, stability, purity, etc. However, the use of living organisms during production makes it difficult to predict and control these processes. For example, biomanufacturing processes involve high levels of uncertainty and batch-to-batch variability. Consequently, achieving high levels of predictability and stability in production can be often challenging. As a result of these challenges, biomanufacturing costs and lead times are often much higher compared to conventional pharmaceutical drug manufacturing applications.

So far, the competitive advantage in biomanufacturing has been mainly driven by the scientific know-how (i.e., the ability to create and re-engineer these innovative active ingredients). However, with recent advances in biomanufacturing technologies and increasing market competition, the competitive advantage is shifting from the scientific know-how to the manufacturing know-how (i.e., the ability to effectively design, control and optimize biomanufacturing systems). As such, most biomanufacturers are looking for innovative ways for reducing their costs and lead times, and subsequently enhance their competitiveness in the market.

The Boxmeer Research and Development Project

The project team consisted of Dr. Tugce Martagan and Prof. Dr. Ivo Adan from TU/e, and Oscar Repping, Bram van Ravenstein and Marc Baaijens from MSD AH. Several Ph.D. and Master's students also contributed. The project was conducted at the Boxmeer facility in the Netherlands, which is one of the largest biomanufacturing hubs in Europe. They conduct research and development as well as large-scale manufacturing, and sell biopharmaceuticals all around the world.

The project team enabled the knowledge from life sciences and industrial engineering (OR) to create solutions tailored to the unique needs of the biomanufacturing industry. "The developed decision support tools capture the biological and chemical dynamics of the underlying processes and then link them to system-level dynamics, such as costs and lead times" says Dr. Martagan. Overall, the project used machine learning and simulation-based optimization to model, control and optimize biomanufacturing systems. The developed solutions also helped operations managers to have a better understanding of the business risks and financial trade-offs. "We achieved 97% higher output without making any investment in resources such as equipment or labour. We achieved this by adopting a data-driven, OR-based approach to optimize our daily decisions" says Bram van Ravenstein, Associate Director at MSD Animal Health.

Overall, the project resulted in the development of three decision support tools.

Tool 1. Reducing Bioreactor Setups

The first developed tool is related to fermentation processes. Typically, fermentation is one of the first production steps in biomanufacturing. The fermentation process is often conducted in bioreactors (e.g., stainless steel vessels) that provide a highly controlled environment for cell growth. The process starts with placing a small amount of seed culture inside the bioreactor along with a fresh medium. As the fermentation evolves over time, the seed culture starts to grow, reproduce and create the active ingredients of interest (e.g., antigens, antibodies, etc.). In a typical fermentation process, the live cells go through several growth phases: First, they incur a *lag phase* where they get adjusted to their new environment inside the bioreactor. Second, they enter an *acceleration phase* where cell growth starts. Next, the cells grow exponentially during the *exponential growth phase*. Once the nutrients start depleting, the cells enter into a *deceleration phase* followed by the *death phase*. The final product of fermentation is often a batch mixture that contains the active ingredients of interest along with several unwanted impurities (e.g., dead cells, unwanted residues, etc.).

Once the fermentation terminates and the batch is harvested, the bioreactor needs to be cleaned and sterilized for the subsequent batch, called the bioreactor setup, which could be time consuming and expensive. To reduce such setups, the team developed an *innovative replenishment technique*. When this new technique is performed, the bioreactor operator extracts a pre-determined fraction of the content that is already present inside the bioreactor, and then adds a special medium. The remaining content behaves as a seed culture for the next round of fermentation, while the content extracted from the bioreactor is sent to the subsequent production steps for further processing.

The new replenishment technique is highly innovative and enables significantly reduced bioreactor setups. However, the technique can be applied only two or three times due to regulatory requirements. In addition, it can be applied only during the exponential growth phase. On the other hand, the time when the exponential growth phase stops is highly variable because of the uncertain behavior of the living cells. This uncertainty leads to an interesting question for practitioners: *What is an optimal time to perform the replenishment technique?* If it is done *too soon*, the system does not achieve its best performance in terms of production yield (i.e., as the fermentation evolves, the cells produce higher amounts of active ingredients). In contrast, if it is done *too late*, then the technique is not effective and the bioreactor needs to be cleaned and sterilized. To address this trade-off, the team developed a *stochastic optimization model* using the *renewal reward theory*. The model

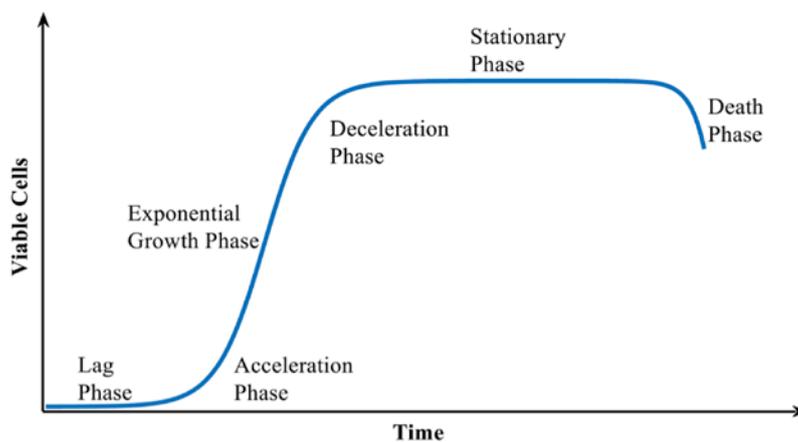


Figure 1: Typical phases of cell growth during fermentation

links the underlying biological dynamics of the fermentation process with financial risks and trade-offs. The model has been calibrated with historical data, and several small-scale test runs were conducted to enhance and validate the model. A user-friendly interface was developed to facilitate the use in daily practice.

Tool 2: Achieving Higher Batch Yield

The second tool is also related to the fermentation operation. The business case of this project was motivated by a sub-optimal performance of a production line at the Boxmeer facility. The main bioreactor in this production line was consistently producing a lower yield (amount of active ingredient) compared to other production lines. Further investigation showed that a critical process parameter needed to be optimized to improve the performance of this recently introduced bioreactor.

As no historical data was available to identify an optimal configuration for this critical process parameter, nor was relevant information reported in the literature, the team needed to conduct experiments to collect this information and identify an optimum configuration. Furthermore, these experiments needed to be conducted at industry-scale with real-world bioreactor runs. This has led to an interesting optimal learning problem, where the team needed to identify the best process configuration using a minimum number of industry-scale experiments.

To address this problem, the team developed a decision support tool using the theory of Bayesian design of experiments. The tool enabled an effective information collection policy through real-world experiments and identified an optimum configuration for the bioreactor. The resulting configuration has been implemented at MSD AH for almost two years and has led to a 50% higher yield per batch.

Tool 3: Optimizing Production Planning and Scheduling Decisions

The third tool captures the overall production process from the time when an order is released to the biomanufacturing system until it is shipped to clients. The main objective of this project was to develop an optimal production plan for the Boxmeer facility. Production planning in biomanufacturing can be often challenging in practice: First, the production process involves several interdependent steps. For example, a product could go over 8,000 different manufacturing steps. This implies that a sub-optimal performance at an earlier step has a magnifying effect on subsequent operations. Second, most biomanufacturing systems have a no-wait constraint. This means that once the production starts, the batch cannot wait between different production steps. Otherwise, the active ingredients would decay or lose stability. In the overall production process, there are only a few stock points where the batch is allowed to wait (if stored in cold temperatures). This no-wait constraint adds an additional challenge in production planning. In addition, several resources are shared and expensive, and not all equipment (or scientists) have similar capabilities.

To address such unique characteristics of biomanufacturing systems, the team first developed a *discrete-event simulation* model. The simulation model was built in the Arena software, and captured all critical production lines of the Boxmeer facility. Next, the simulation model was linked to an optimization module that used a Tabu search algorithm to generate better production plans. The resulting production plans were implemented at MSD AH and enabled one extra batch each week to be produced, without expanding the existing capacity.



▲ Boxmeer Plant

Impact

The involvement of management and production staff at MSD AH in the project team enabled the company to understand and appreciate the value of the new tools, such that approval by senior management for their introduction became a formality. After appropriate training for the planners, the tools were introduced in August 2017 and have enabled a 97% higher output in the Boxmeer facility without investing in new equipment or labour. In addition, the project enabled a better understanding of the business risks and financial trade-offs, and encouraged a data-driven, OR-based approach in daily decision-making. As Oscar Repping, Executive Director at MSD AH states, "We [the industry] will benefit from OR, as such, we will avoid investments, we will become more predictive, leading to cost reduction, leading to more capacity on our production lines, meaning that we can make this world a better place." As more companies adopt an OR-based approach to improve their biomanufacturing efficiencies, we believe that the long term impact will be significant for society by enabling cheaper access to life-saving drugs.

Reference

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AN OR APPLICATION IN ARGENTINA: OPTIMIZING LEAF SWEEPING AND COLLECTION IN THE CITY OF TRENQUE LAUQUEN

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Some 445 km west of the Argentine capital of Buenos Aires lies the city of Trenque Lauquen, home to 33,000 residents distributed across its surface area of about 400 hectares. A distinctive characteristic of the city is the wide medians running down the centre of most streets that have been planted with a diverse range of tree species. In all, there are 616 street blocks with treed medians. The result is a high ratio of green space per inhabitant, but also a constant need for street sweeping and collection to prevent leaves from accumulating along the curbs, blocking storm drains and making road surfaces slippery.

The Trenque Lauquen municipal authorities operate two different leaf sweeping systems. One is mechanical, which consists in using street cleaning vehicles to sweep the median curbs. The present study, however, is confined to the other system, which uses human sweepers equipped with brooms and bag-lined leaf collection carts to clean up the leaves and other waste that collect along the curbs bordering the sides of each block. Over the entire city there are approximately 1,800 such block sides that must be swept manually.

When work on this study began, the manual collection system employed 84 sweepers deployed across three leaf sweeping zones into which the city is divided. Zone 1 had 21 sweepers and 629 block sides, Zone 2 had 35 sweepers and 678 block sides and Zone 3 had 28 sweepers and 507 block sides. This zonal division, shown on the map in Figure 1, is maintained by the municipal authorities for administrative reasons and is considered for present purposes as a given. The four sweeper route starting points are also indicated on the map.

The result of this daily assignment system was that each sweeper tended to improvise their own routes as they went, depositing bags of leaves at any and every intersection. Collection trucks working the same shift picked up the bags and drove them to a rubbish dump 7 kilometres west of the city. Bag pickup in each zone was handled by two trucks.

This “manually” organized setup previous to the strategy developed in this study was unsatisfactory for a number of reasons, among which were the following:

- **No stable, well-defined routes:** Many blocks were not swept with the minimum expected frequency.
- **Poor distribution of sweepers among zones:** The number of block sides per day swept by each sweeper was supposed to average 20 to 24, but in practice, sweepers in Zone 1 were averaging almost 30 block sides per day, while those assigned to Zones 2 and 3 were averaging only about 19 and 18, respectively.
- **Bad coordination between collection trucks and**



▲ Figure 1: City leaf sweeping zones and sweeper route starting points.

sweepers: The sweeping and collection tasks were not properly sequenced, due mainly to the fact that sweepers and collection trucks worked the same hours.

In light of these deficiencies, the objectives set for the solution strategies presented in this study were as follows:

1. Determine whether the number of sweepers under the manual system was sufficient (this was the main objective of the municipal authorities). Generate a leaf sweeping plan and feasible sweeper routes that would satisfy the desired sweep frequencies for each block.
2. Determine the intersection corners where sweepers were to deposit the leaf bags in containers placed there by the municipality for the purpose.
3. Define collection truck routes that optimized vehicle use and work time.

A solution strategy based on integer linear programming models was developed. The aim was to achieve efficiency in the assignment of sweepers to city blocks, the identification of leaf bag deposit points and the routes to be followed by collection trucks for leaf bag pickup. Application of the solution strategy by the city has resulted in efficient definitions of sweeper requirements while optimizing sweeper assignments such that all blocks are covered. >>

>> Once the strategy is fully implemented, the number of bag deposit points should be reduced by roughly one-half relative to the manual definitions and total travel distance of the truck routes, modelled as an asymmetric travelling salesman problem, should be shortened by 10 to 15% with the consequent savings in time, vehicle use and fuel consumption.

The first stage of the strategy determines which blocks are swept by which sweeper. The solution approach for this stage is an adaptation of the integer linear programming (ILP) model that was developed for the 2010 Argentine census to assign census workers to blocks [1].

	Zone 1	Zone 2	Zone 3	Total
No. of block sides	629	678	507	Total
No. of sweepers before (manual)	21	35	28	84
No. of sweepers after (model, average)	31	38	23	92
Variation in no. of sweepers	+48%	+8%	-18%	+9%

The second stage of the strategy determines the order in which sweepers visit each block side within their assigned blocks and the corners at which they deposit the leaf bags in containers placed there by the municipality. Finally, the third stage traces out the routes to be followed by the leaf bag collection trucks. Once the container locations have been determined, this stage defines the order in which the leaf bags deposited in the containers are collected in such a way as to reduce the total distance travelled. This problem is formulated as an asymmetric travelling salesman problem and is solved using the Concorde solver, thus identifying the shortest collection truck route that visits all the container location.

Given that actual sweep times for a block side may vary depending on the sweeper's work pace, it was decided that we would consider a "standard" scenario (12 minutes per 100 metres), a "fast" scenario (10 minutes per 100 metres) and a "slow" scenario (14 minutes per 100 metres).

The definitive solution assignments obtained by the model for Zone 1 are shown for the fast, standard and slow scenarios from left to right in Figure 2 (each colour defines an assignment for each sweeper). The corresponding number of sweepers in the three scenarios were 28, 31 and 35, respectively.

The following table shows the results of the stage 1 with both manual and model assignment.

As can be seen, sweeper numbers in relation to the number of block sides were not deployed to the three zones in equal proportion. The change in assigned sweepers under the model implies that the manual Zone 3 assignments were too high while those for Zone 2 were slightly too low and those for Zone 1 were significantly too low. The model solutions generated accurate estimates of the number of sweepers required in each zone to ensure all block sides are swept, thereby also indicating how many additional workers were needed.

Since Stage I was still in the process of implementation at the time of writing, the scenario best suited to each zone has not yet been decided so the results for Stages II and III presented here are based on the standard scenario (31 sweepers) for Zone 1, shown in the centre diagram of Figure 2.

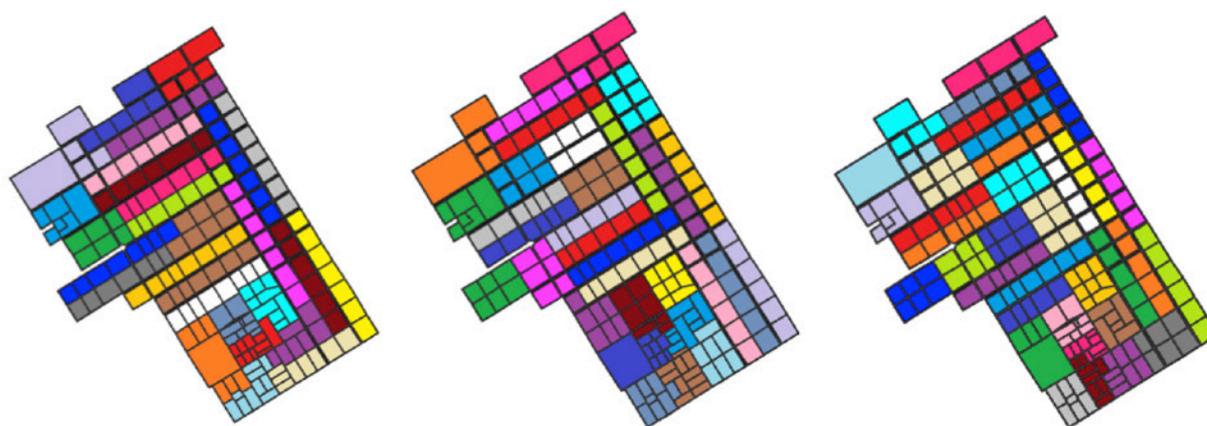
Our model generated a solution for this instance that required 111 container locations. Under the manual system, leaf bags could be deposited at any intersection an arrangement that clearly is very inefficient. In Zone 1 the number of intersections previously used as deposit points was about 240, more than double the number in the model solution or a reduction of 53.75 %.

The instances of the collection truck route problem (stage III) are small and thus were solved by Concorde in a matter of seconds. With the manual system, since leaf bags were deposited at any corner, the collection trucks had to zigzag their way along every block side in the city. By contrast, the route determined by the model, though perhaps more irregular in shape, is much shorter. In numerical terms, the reduction for the two trucks used to cover Zone 1 is from 32.2 km to 28.4 km (13.7 km and 14.7 km for the northern and southern sections, respectively), a savings of 12% in total driving distance with the consequent reduction in fuel consumption.

Trenque Lauquen municipal officials are very satisfied with the results of the solution strategy as implemented so far and have expressed an interest in applying OR-based solutions to other aspects of its daily activities. According to Mayor Miguel Fernández, "we feel this type of analysis allows us to make better-informed decisions and should be considered for application to other areas where there is potential for optimizing the use of available resources."

References

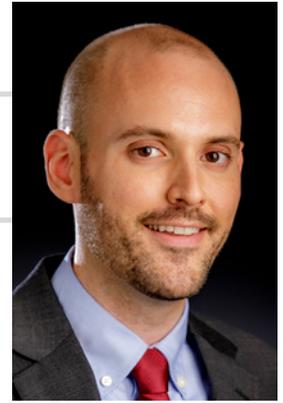
[1] Bonomo F., Delle Donne D., Duran G., Marengo J. "Automatic Dwelling Segmentation of the Buenos Aires Province for the 2010 Argentinian Census", *Interfaces* 43(4):373-384, 2013. 



▲ Figure 2: Definitive assignments in Zone 1 for the fast, standard and slow scenarios (left, centre and right diagrams, respectively).

A BRIEF TUTORIAL ON GOMORY CUTS

Austin Buchanan and Mohammad Javad Naderi



Integer programs (IPs) are solved in practice by branch-and-cut algorithms. These algorithms rely heavily on cutting planes, which are inequalities that are added to linear programming (LP) relaxations to cut off (bad) fractional points, but not the (good) integer feasible points. The classical cutting planes for solving IPs were developed by Ralph Gomory in the late 1950s, motivated in part by his time as a consultant for the US Navy (Gomory, 2010):

As the Navy had kept me on as a consultant I continued to work on Navy problems through monthly trips to Washington. On one of these trips a group presented a linear programming model of a Navy Task Force. One of the presenters remarked that it would be nice to have whole number answers as 1.3 aircraft carriers, for example, was not directly usable.

Within the next few weeks, Gomory had developed his technique for generating cutting planes based on the simplex tableau. Soon after, he proved that his algorithm was finite and programmed it on the E101, allowing him to solve five-variable problems reliably(!). In this tutorial, we briefly discuss Gomory's fractional cuts and his subsequently developed mixed integer cuts, which are used by modern IP solvers to handle much-larger-than-five-variable problems reliably (Gleixner et al., 2019).

1 Gomory fractional cuts

Let's begin with the following IP.

$$\max x_1 + x_2 \tag{1a}$$

$$x_1 - 2x_2 \leq 4 \tag{1b}$$

$$x_1 + 3x_2 \leq 11 \tag{1c}$$

$$x_1, x_2 \geq 0 \tag{1d}$$

$$x_1, x_2 \text{ integer.} \tag{1e}$$

The associated LP relaxation is shown in Figure 1. Adding (integer-valued) slack variables gives:

$$\max x_1 + x_2 \tag{2a}$$

$$x_1 - 2x_2 + x_3 = 4 \tag{2b}$$

$$x_1 + 3x_2 + x_4 = 11 \tag{2c}$$

$$x_1, x_2, x_3, x_4 \geq 0 \tag{2d}$$

$$x_1, x_2, x_3, x_4 \text{ integer.} \tag{2e}$$

Solving the LP relaxation gives the following system, with objective $z = x_1 + x_2$

$$z + 0.4x_3 + 0.6x_4 = 8.2 \tag{3a}$$

$$x_1 + 0.6x_3 + 0.4x_4 = 6.8 \tag{3b}$$

$$x_2 - 0.2x_3 + 0.2x_4 = 1.4 \tag{3c}$$

$$x_1, x_2, x_3, x_4 \geq 0. \tag{3d}$$

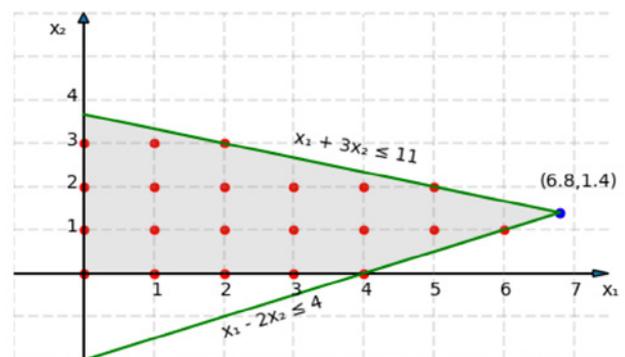
This corresponds to the fractional point $(x_1, x_2, x_3, x_4) = (6.8, 1.4, 0, 0)$.

A first cut. In any feasible solution to the IP, x_1 will take an integer value, so from equation (3b) we can write $0.6x_3 + 0.4x_4 = 0.8 + k$ for some integer k . Notice that the left side of this equation can only take nonnegative values, so the right side must as well, i.e., $0.8 + k \geq 0$ or $k \geq -0.8$. Since k is an integer, we know that $k \geq 0$. So, $0.6x_3 + 0.4x_4 = 0.8 + k \geq 0.8$. We have just argued for the Gomory fractional cut:

$$0.6x_3 + 0.4x_4 \geq 0.8.$$

By equations (2b) and (2c) we can express this inequality as:

$$x_1 \leq 6.$$



▲ Figure 1: LP relaxation.

This inequality, shown in Figure 2, cuts off our fractional point $(6.8, 1.4, 0, 0)$.

A second cut. Now consider the equation (3c). As before, we can write $-0.2x_3 + 0.2x_4 = 0.4 + k$ for some integer k . However, the left side of this equation may not always take nonnegative values (due to the negative coefficient for x_3), so our previous argument will not work. However, if we add x_3 to both sides, we can write $0.8x_3 + 0.2x_4 = 0.4 + p$ for some (other) integer p . Using the same argument as before, we can generate another Gomory fractional cut:

$$0.8x_3 + 0.2x_4 \geq 0.4.$$

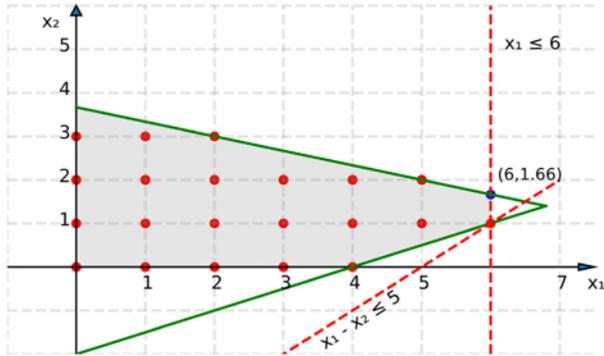
By equations (2b) and (2c) we can express this inequality as

$$x_1 - x_2 \leq 5.$$

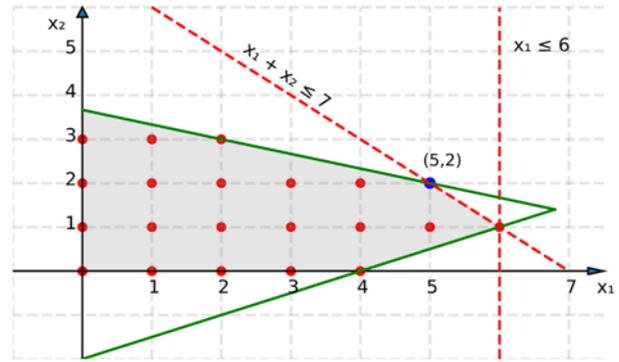
This inequality, also shown in Figure 2, cuts off our fractional point but is less helpful than the first cut.

The general case. We can write the Gomory fractional cut in more general terms as follows. Suppose that nonnegative integers x_1, x_2, \dots, x_n satisfy the equation $\sum_{i=1}^n a_i x_i = b$, where b is fractional, i.e., $b \notin \mathbb{Z}$. Think of this as a row of the simplex tableau (dictionary). The associated Gomory fractional cut is:

$$\sum_{i=1}^n (a_i - \lfloor a_i \rfloor) x_i \geq b - \lfloor b \rfloor.$$



▲ Figure 2: Gomory fractional cuts.



▲ Figure 3: Gomory mixed integer cuts.

Proposition 1. The Gomory fractional cut (4) is valid for the set $X = \{x \in \mathbb{Z}_+^n \mid \sum_{i=1}^n a_i x_i = b\}$.

Proof. Let $x^* \in X$. We are to show that $\sum_{i=1}^n (a_i - \lfloor a_i \rfloor) x_i^* \geq b - \lfloor b \rfloor$. By $x^* \in X$, the equality $\sum_{i=1}^n a_i x_i^* = b$ holds. Since each $\lfloor a_i \rfloor$ is integer, and since each x_i^* is integer, we can write $\sum_{i=1}^n (a_i - \lfloor a_i \rfloor) x_i^* = b - \lfloor b \rfloor + k$, for some integer k . Observe that the left side is nonnegative, so the right side is as well, $b - \lfloor b \rfloor + k \geq 0$ and thus $k \geq \lfloor b \rfloor - b > -1$. By $k \in \mathbb{Z}$, this implies $k \geq 0$. So, in conclusion,

$$\sum_{i=1}^n (a_i - \lfloor a_i \rfloor) x_i^* = b - \lfloor b \rfloor + k \geq b - \lfloor b \rfloor.$$

Two observations:

1. Subtracting $\lfloor a_i \rfloor$ from a_i in the Gomory fractional cut ensures that the left side is nonnegative, which was key to our arguments. We could have instead subtracted some other number $q < \lfloor a_i \rfloor$ from a_i and the resulting inequality would remain valid; however, this would weaken the inequality.

2. The Gomory fractional cut remains valid when you add other constraints to the set X . This means you can still use it when your IP is more complicated.

2 Gomory mixed integer cuts (for pure IPs)

We have just seen Gomory fractional cuts. However, they are not used in practice. A primary reason is that they are subsumed by Gomory mixed integer (GMI) cuts, which Gomory introduced just two years later.

GMI cuts have two advantages over Gomory fractional cuts. First, they are more general in the sense that they apply when the problem has a mix of integer and continuous variables (MIPs), whereas Gomory fractional cuts only apply for problems in which all variables are integer (pure IPs). A second advantage is that even when dealing with pure IPs, GMI cuts are just as strong or stronger than Gomory fractional cuts.

For simplicity, we will stick with pure IPs in this tutorial. The interested reader is invited to consult the longer tutorial by Cornu'ejols (2008) for the full version of GMI cuts.

The general case. Again, suppose that nonnegative integers x_1, x_2, \dots, x_n satisfy the equation $\sum_{i=1}^n a_i x_i = b$, where b is fractional. Letting $I = \{1, \dots, n\}$, the associated GMI cut is:

$$\sum_{i \in I: f_i \leq f} \frac{f_i}{f} x_i + \sum_{i \in I: f_i > f} \frac{1 - f_i}{1 - f} x_i \geq 1. \quad (5)$$

This inequality uses the fractional parts of b and a_i , which are denoted $f := b - \lfloor b \rfloor$ and $f_i := a_i - \lfloor a_i \rfloor$. Each is non negative. Notice that if $f_i \leq f$ for every i , then the resulting GMI cut is exactly the same as the Gomory fractional cut, which can be written in terms of the f notation as:

$$\sum_{i \in I} f_i x_i \geq f. \quad (6)$$

However, if at least one i satisfies $f_i > f$, then the GMI cut is stronger. This is because if $f_i > f$, then $\frac{1 - f_i}{1 - f} < \frac{f_i}{f}$, meaning the coefficient of x_i will be smaller.

To illustrate GMI cuts, recall the system identified previously:

$$z + 0.4x_3 + 0.6x_4 = 8.2 \quad (7a)$$

$$x_1 + 0.6x_3 + 0.4x_4 = 6.8 \quad (7b)$$

$$x_2 - 0.2x_3 + 0.2x_4 = 1.4 \quad (7c)$$

$$x_1, x_2, x_3, x_4 \geq 0. \quad (7d)$$

A first cut. In equation (7b), we have $f = 0.8$, $f_1 = f_2 = 0$, $f_3 = 0.6$, and $f_4 = 0.4$. Notice that $f_1, f_2, f_3, f_4 \leq f$, and the resulting inequality is exactly the same as the Gomory fractional cut:

$$\frac{0.6}{0.8} x_3 + \frac{0.4}{0.8} x_4 \geq 1,$$

which, by equations (2b) and (2c), can be expressed as:

$$x_1 \leq 6.$$

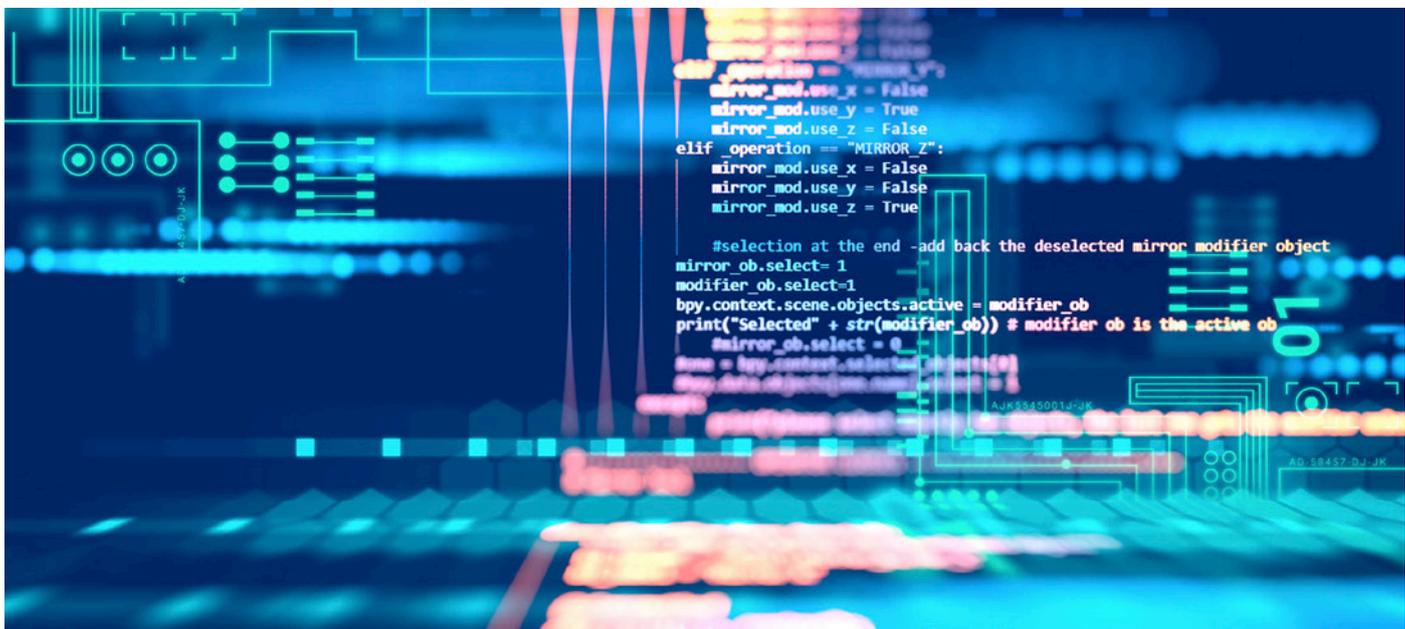
A second cut. Now consider equation (7c), which has $f = 0.4$, $f_1 = f_2 = 0$, $f_3 = 0.8$, and $f_4 = 0.2$. Notice that $f_1, f_2, f_4 \leq f$ and $f_3 > f$, and the resulting GMI cut is:

$$\frac{1 - 0.8}{1 - 0.4} x_3 + \frac{0.2}{0.4} x_4 \geq 1.$$

By equations (2b) and (2c) we can express this inequality as:

$$x_1 + x_2 \leq 7,$$

which is shown in Figure 3.



Re-solving the LP relaxation after adding GMI cuts gives the solution $(x_1, x_2) = (5, 2)$, which is optimal for the IP. Meanwhile, one round of Gomory fractional cuts still gives a fractional solution (see Figure 2)

Proposition 2. *The Gomory mixed integer cut (5) is valid for the set $X = \{x \in \mathbb{Z}_+^n \mid \sum_{i=1}^n a_i x_i = b\}$.*

Proof. Our task is to show that every $x^* \in X$ satisfies inequality (5). So, let $x^* \in X$. This implies that

$$\sum_{i \in I} a_i x_i^* = b. \quad (8)$$

and $x^* \in \mathbb{Z}_+^n$. Since $\lfloor a_i \rfloor$ and $\lfloor b \rfloor$ and x_i^* are integers, and by equation (8), we can write

$$\sum_{i \in I: f_i \leq f} (a_i - \lfloor a_i \rfloor) x_i^* + \sum_{i \in I: f_i > f} (a_i - \lfloor a_i \rfloor - 1) x_i^* = b - \lfloor b \rfloor + k$$

for some integer k . In terms of our f notation, this is

$$\sum_{i \in I: f_i \leq f} f_i x_i^* + \sum_{i \in I: f_i > f} (f_i - 1) x_i^* = f + k.$$

We consider two cases. In the first case, suppose that $k \geq 0$, in which case

$$\begin{aligned} \sum_{i \in I: f_i \leq f} \frac{f_i}{f} x_i^* + \sum_{i \in I: f_i > f} \frac{1-f_i}{1-f} x_i^* &\geq \sum_{i \in I: f_i \leq f} \frac{f_i}{f} x_i^* + 0 \\ &\geq \sum_{i \in I: f_i \leq f} \frac{f_i}{f} x_i^* + \sum_{i \in I: f_i > f} \frac{f_i-1}{f} x_i^* \\ &= \frac{f+k}{f} \geq 1. \end{aligned}$$

The last equation holds by (9). The last inequality holds by $k \geq 0$ and $f > 0$. In the other case, suppose $k < 0$. Then, $k \leq -1$ since k is an integer, so

$$\begin{aligned} \sum_{i \in I: f_i \leq f} \frac{f_i}{f} x_i^* + \sum_{i \in I: f_i > f} \frac{1-f_i}{1-f} x_i^* &= \sum_{i \in I: f_i \leq f} \frac{f_i}{f} x_i^* + \sum_{i \in I: f_i > f} \frac{f_i-1}{f-1} x_i^* \\ &\geq 0 + \sum_{i \in I: f_i > f} \frac{f_i-1}{f-1} x_i^* \\ &\geq \sum_{i \in I: f_i \leq f} \frac{f_i}{f-1} x_i^* + \sum_{i \in I: f_i > f} \frac{f_i-1}{f-1} x_i^* \\ &= \frac{1}{f-1} (f+k) \geq 1. \end{aligned}$$

The last equation holds by (9). The last inequality holds by $k \leq -1$ and $f-1 < 0$. So, x^* satisfies the GMI inequality (5) in both cases, and so the GMI inequality is valid for X .

Further reading. Consult Cornu'ejols (2008) for a definitive account of these and other valid inequalities for MIPs. Also see the video lectures by Krishnamoorthy (2019) and Pen'ã (2016)

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AFROS: THE ORMS HOPE OF AFRICA

Hatem Masri <email>, President of the African Federation of Operations Research Societies (<http://www.afrosocieties.org/>), Dean of the College of Business Administration at the University of Bahrain (<http://www.uob.edu.bh/en/>)



On 3rd November 2016 and with the support of IFORS President (Michael Trick) and the Chair of IFORS Developing Countries Committee (Sue Merchant) a group of African ORMS researchers met in Nairobi to discuss a mega project for AFRICA: The African Federation of Operations Research Societies (AFROS). Charles Malack Oloo, from Kenya, was designated as the first president of AFROS with a mandate to organize its inaugural conference in 2018. The Tunisian Decision Aid Society with the help of IFORS, EURO and IHE Paris organized the 2018 AFROS conference, with a program of 108 papers from 22 countries (<http://afros.tdasociety.org/>). During the last three years, several meetings were organized among Executive Committee members to discuss how we can promote OR in Africa and foster research collaboration between African ORMS researchers. As a result of these interactions, a new OR society was established in Kenya and we are expecting more to come in the coming year.

- President: Hatem Masri (Tunisia)
- Past President: Charles Malack Oloo (Kenya)
- Secretary and Treasurer: Bernie Lindner (South Africa)
- Database manager/webmaster: SerigneGueye (Senegal)
- Public relations manager: Fouad Ben Abdelaziz (Tunisia)

The new Executive Committee will have a critical task to define a Strategy that allows AFROS to be recognized by IFORS as a hub of OR in Africa. The next AFROS 2021 conference, organized by ORSSA in South Africa, will be the right timing to announce the new strategy and gather efforts to materialize it.

AFROS should benefit from other IFORS regional groups (ALIO, APORS and EURO) and their experiences enhancing research collaboration in other regions. The EURO Working Groups is one of the success stories that brought a lot of research activity in Europe and could inspire AFROS.

Logistics, transportation and regulations are a real handicap for African researchers to meet in one place but new technologies can help us to overcome this physical problem. AFROS should build a series of webinars and virtual events to bridge between these research unit in Africa.

In all cases, we can't encourage ORMS research in Africa without the support of industry. AFROS should look for a generous sponsor that could help us to raise funds for our upcoming conference AFROS 2021 in South Africa. 🌐



In 19 December 2019, the first elections resulted in a new Executive Committee of AFROS:

AIROYOUNG GROUP

Gradually, indeed, OR-related companies began to grow their interest in the AIROYOUNG group as a good starting point in searching for new employees. AIROYOUNG have created something unique and special for all young academics and practitioners. AIROYOUNG is born as an arm of the Italian national OR association AIRO in 2016 and it is committed as a community of researchers and practitioners under 35 years or people with less than 5 years after obtaining the PhD. Its main mission is to create a network between young researchers and industry, and to offer opportunities to all PhD students, independently from their funds. Inclusion is a key word in AIROYOUNG, and the board of the chapter, as well as the organizers of our workshops, put their time and enthusiasm to organize resources (through our website)



▲ Martina Fischetti, Lavinia Amorosi, Valentina Morandi, Alice Raffaele and Serena

and events (our early workshop in particular) that can be accessible to everybody. Thanks to the sponsorship from AIRO, from host universities and privates, we have been able to organize every year a workshop completely free of charge for the attendees and to provide grants to help students with accommodation expenses during the event. This was possible due to our sponsors, and in particular to the 3 young researchers (Tiziano Parriani, Martina Fischetti and Valentina Morandi) that devolved prizes they have won to AIROYOUNG as this also shows the commitment of the Italian OR community to AIROYOUNG.



▲ 3rd AIROyoung workshop in Rome, 2019

AIROyoung is devoted not only to create a network between young researchers in OR, but also to support them, keeping them updated on the most innovative research streams and on the most interesting conferences and, last but not least, to let AIROyoung members aware of open positions in industry and in academia. The first step in this direction was made by building a web portal in which each AIROyoung researcher could insert his/her CV to be known by the OR community as a repository of Young OR talents. In addition, the web portal works as a repository for events (i.e. conferences, summer/winter schools, workshops), for tutorials to increase the AIRO youngers knowledge, for announcements about new research streams and for new open positions in the academic field and in industry.

Gradually, indeed, OR-related companies began to grow their interest in the AIROyoung group as a good starting point in searching for new employees. Thus, they started advertising their open positions on the AIROyoung portal increasing the service level for our members. The portal offers also a talent section, where young researchers can post their CV. This represents, as of today, a unique catalogue of young OR practitioners on the job market and is therefore of key values for recruitment. The portal currently sees the submission of 59 young researchers (some of them coming from abroad) and calls for 345 job opportunities both in the academic and industrial fields. But that is not all: the AIROyoung web portal offers tutorials on the use of optimizers, web seminars on various topics and many other contents.

AIROyoung is now much more than the web portal and it went so far as to set up its own conference dedicated to young people: the annual AIROyoung workshop. The first AIROyoung workshop was held in Rome in 2017 and it had a remarkable success with high level invited talks and a good participation. In the following years, the AIROyoung workshop moved to Cosenza and, then, back to Rome with a continuously growing number of participants and high-level speakers giving plenary talks. In particular, in

conjunction with the last workshop in Rome, AIROyoung implemented an interesting experiment, the 1st AIROyoung PhD School, i.e. the first school for OR PhD students with tutorials and lectures given by AIROyoung researchers. The participants were enthusiastic about both the format and the contents of the school. Now, the fourth workshop is going to be held in Bolzano, and we expect an increasing participation and new exciting ideas will be implemented. As a novelty for the next workshop, we will leave room for academics and practitioners coming from data science and machine learning fields in order to let AIROyoungers be aware of the new findings in these multidisciplinary fields and we will propose a pitch talks round table session for early stage PhD student. The later will be done in order to provide some insights to new researchers and to know what it is brewing in the field. As in the previous years, AIROyoung workshop was able to attract funds from academic and industrial institutions in recognition of the service done to the OR community. And if that wasn't enough, AIROyoung guarantees its presence in most of the national and international OR conferences with dedicated streams for AIROyoungers and also young practitioners sessions to foster the collaboration among academia and industry.

As a bite of history, the first founders of the AIROyoung group were Lavinia Amorosi, Veronica Dal Sasso, Martina Fischetti and Alberto Santini. The steering committee has enlarged over the years because of the many ongoing and to-be activities, and a more formal structure has been created. Today, it consists of two coordinators (Lavinia Amorosi and Martina Fischetti), a treasurer (Valentina Morandi) and two social media managers (Serena Fugaro and Alice Raffaele). The team is, now essential in order to guarantee the success of the AIROyoung activities and, despite the enormous effort required, we are all satisfied with the results achieved and the awards obtained at international level. The AIROyoung web portal is available at the web address: <https://www.airoyoung.org/> and we are particularly active on the main social media. So, stay tuned... 🌐



NACA-ICOTA 2019: OPTIMIZATION, OR AND FRIENDSHIP IN HAKODATE, JAPAN

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International Conference on Nonlinear Analysis and Convex Analysis-International Conference on Optimization: Techniques and Applications was held at Future University Hakodate, Japan, August 26–31, 2019 (<http://wgnaca.org/naca-icota2019/>).

NACA conference series is organized by *International Research Working Group in Nonlinear Analysis and Convex Analysis (WGNACA)*, aiming to get together worldwide experts on nonlinear analysis and convex analysis, to exchange scientific information on generic and applied areas of the conference, to discuss recent advances in theoretical and applicable aspects of such topics.

ICOTA conference series is an official conference series of *Pacific Optimization Research Activity Group (POP)*, which collaborates with *EURO* and *IFORS* for many years. Its aims to provide an international exchange forum of ideas, to present research findings and solutions, to share experiences on potentials and limits, to open new research and development, on every issue of optimization. This time, two conferences cooperated in all aspects concerning the various fields aforementioned.

First NACA conference took place in Niigata, 1998, and the second was held in Hirosaki, 2001. Then, NACAs have been held biannually: The third in Tokyo, 2003, fourth in Okinawa, 2005, fifth in Hsinchu, 2007, sixth in Tokyo, 2009, seventh in Busan, 2011, eighth in Hirosaki, 2013, ninth in Chiang Rai, 2015, and tenth in Chitose, 2017.

First two ICOTA conferences took place in Singapore in 1987 and 1992, after which ICOTA has become an important series run by a steering committee. The third ICOTA conference was held in Chengdu, 1995, and fourth in Perth, 1998. Fifth-tenth ICOTAs were held in Hong Kong, 2001, Ballarat, 2004, Kobe, 2007, Shanghai, 2010, Taipei, 2013, and Ulaanbaatar, 2016.

NACA-ICOTA 2019 was the 11th meeting for both NACA and ICOTA, as a milestone for research activity related to nonlinear and convex analyses, optimization, and their applications.

Topics were so rich:

NACA Section:

Nonlinear Analysis: Nonlinear Functional Analysis, Fixed Point Theory, Ergodic Theory, Fixed-Point Approximations, Proximal-Point Algorithms, Nonlinear Differential Equations, Evolution Equations, Partial Differential Equations and Applications, Geometry of Banach Spaces, Convex Analysis, Set-Valued Analysis, Minimax Problems, Equilibrium Problems, etc.. **Optimization Theory:** Vector Optimization, Set Optimization, Nonlinear Optimization, Global Optimization, Combinatorial Optimization, Dynamic Programming, Calculus of Variations, Extremal Problems, Optimal Control Theory, System Theory, etc. **Related Topics:** Game Theory, Mathematics of Finance and Engineering, Data Mining, Neural Networks, etc.

ICOTA Section:

Optimization Theory and Numerical Algorithms:

Linear Programming, Nonlinear Programming, Integer Programming, Network Programming, Semi-Definite Programming, Stochastic Programming, Dynamic Programming, Optimal Control, Global Optimization, N o n s m o o t h Optimization, Semi-Infinite Programming, Multi-Objective Optimization, Variational Inequalities, Complementarity Problems, Mathematical Programs with Equilibrium Constraint, etc. **Algorithms:** Design, Analysis, Implementation of Traditional Mathematical Programming Methodology, Modern Techniques like Meta-Heuristic for Combinatorial and Continuous Optimization, etc. **Applications:** Engineering, Nonlinear Systems, Stochastic System Control, Data/Text Mining from Large Databases, Intelligent Information and Technology, Systems Science, Knowledge Management, Information and Communication Networks, Transportation, Scheduling, Logistics, Finance, Game Theory, Industrial Engineering, Management Science, etc.

Plenary or Semi-plenary Lectures:

Keynote Lectures: Prof. Terry Rockafellar (University of Washington, USA), Prof. Wataru Takahashi (Tokyo Institute of Technology, Japan).

Honorary Lectures: Prof. Charles Castaing (Universite Montpellier II, France), Prof. Sompong Dhompongsa (King Mongkut's University of Technology Thonburi, Thailand), Prof. Shu-Cherng Fang (North Carolina State University, USA), Prof. Kazimierz Goebel (Maria Curie-Sklodowska University, Poland), Prof. Hideaki Iiduka (Meiji University, Japan), Prof. Do Sang Kim (Pukyong National University, Korea), Prof. Anthony To-Ming Lau (University of Alberta, Canada), Prof. Kiyohito Nagano (Gumma University, Japan), Prof. Mau-Hsiang Shih (China Medical University Hospital, Taiwan), Prof. Yuichi Takano (University of Tsukuba, Japan), Prof. Christiane Tammer (Martin-Luther-Universität Halle-Wittenberg, Germany), Prof. Kok Lay Teo (Curtin University, Australia).

Distinguished Lectures: Prof. Jein-Shan Chen (National Taiwan Normal University, Taiwan), Prof. Yuhong Dai (Chinese Academy of Sciences, China), Prof. Deren Han (Beihang University, China), Prof. Hidefumi Kawasaki (Kyushu University, Japan), Prof. Yasunori Kimura (Toho University, Japan), Prof. Gue Myung Lee (Pukyong National University, Korea), Prof. Masakazu Muramatsu (The University of Electro-Communication, Japan), Prof. Kazuo Murota (Tokyo Metropolitan University, Japan), Prof. Koichiro Naito (Kumamoto University, Japan), Dr. Takayuki Okuno (RIKEN Center for Advanced Intelligence Project, Japan), Prof. Nobusumi Sagara (Hosei University, Japan), Prof. Suthep Suantai (Chiang Mai University, Thailand), Prof. Keiji Tatsumi (Osaka University, Japan), Prof. Ngai-Ching Wong (National Sun Yat-sen University, Taiwan), Prof. Hong-



Kun Xu (Hangzhou Dianzi University, China), Prof. Akiko Yoshise (University of Tsukuba, Japan).

Invited Lectures: Prof. Ellen H. Fukuda (Kyoto University, Japan), Prof. Fan Jinyan (Shanghai Jiao Tong University, China), Prof. Jong Soo Jung (Dong-A University, Korea), Prof. Hyun-Min Kim (Pusan National University, Korea), Prof. Jong-Kyu Kim (Kyungnam

University, Korea), Prof. Tae-Hwa Kim (Pukyong National University, Korea), Prof. Wah June Leong (University of Putra, Malaysia), Prof. Yongdo Lim (Sungkyunkwan University, Korea), Prof. Lai-Jiu Lin (National Changhua University of Education, Taiwan), Prof. Xinwei Liu (Hebei University of Technology, China), Prof. Bruno Figueira Lourenço (The University of Tokyo, Japan), Prof. Yasushi Narushima (Keio University, Japan), Prof. Satit Saejung (KhonKaen University, Thailand), Prof. Hiroyuki Sato (Kyoto University, Japan), Prof. Ruey-Lin Sheu (National Cheng Kung University, Taiwan), Prof. Tamaki Tanaka (Niigata University, Japan), Prof. Honglei Xu (Curtin University, Australia).

A special festive session was held at NACA-ICOTA 2019. **Professor Wataru Takahashi** celebrated his 75th birthday in January 2019. He is a founding member of *International Conference of Nonlinear Analysis and Convex Analysis (NACA)*; NACA-ICOTA2019 is the 11th conference, jointly held with ICOTA. Prof. Takahashi is famous for his research in nonlinear analysis including nonlinear ergodic theory for nonexpansive semigroups, fixed point theorems for nonlinear mappings, studies of convex metric spaces, and a p p r o x i m a t i o n theory of fixed points with very strong impact in nonlinear analysis. Professors Anthony To-Ming Lau, Hidetoshi Komiya, and Yasunori Kimura organized the special session to honor Prof. Takahashi, including the speakers Prof. Anthony To-Ming Lau, Prof. Kazuo Murota, Prof. Ngai-Ching Wong, Prof. Satit Saejung, and Prof. Fumiaki Kohsaka.



▲ Professor Wataru Takahashi.

More than 200 participants from 17 countries worldwide attended our conference to exchange information on the latest research results and to enjoy the city of Hakodate! Participants agreed to meet again at the next NACA or ICOTA, and NACA-ICOTA2019 ended very successfully. 🌐



5TH INTERNATIONAL CONFERENCE 2020 NUMERICAL ANALYSIS AND OPTIMIZATION, OMAN

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▲ Participants of the Conference NAOV-2020, Muscat, Oman (outside College of Science, SQU).

The Fifth International Conference on Numerical Analysis and Optimization (NAOV-2020) was held on January 6-9, 2020, at **Sultan Qaboos University**, Muscat, Oman (website: conferences.squ.edu.om/naov-2020). This conference is one of the few opportunities in the Middle East and Arab Gulf region that brings together once every three years many prominent mathematicians, OR scholars, scientists, engineers, worldwide experts and active researchers from prestigious Universities, National Laboratories and Research Institutions, National Academic of Sciences in the fields of Optimization and Numerical Analysis to give presentations of novel and advanced applications on their latest work in engineering and science to facilitate cross-fertilization among various key sectors of pure scientific and applied knowledge. The first conference (NAO-2008) was held in April 6-8, 2008; the second conference (NAOII-2011) in January 3-6, 2011; the third conference (NAOIII-2014) in January 5-9, 2014; and the fourth conference (NAOIV-2017) in January 2-5, 2017. Hopefully, the conference will also provide the opportunity for worldwide experts from the US and North America, Europe, Asia and Arab countries gather and meet to simulate the communication of new innovative ideas, promote scientific exchange and discuss possibilities of further cooperation, networking and promotion of mobility of senior and young researchers and PhD and MSc students.

Many real-world complex problems can be formulated as optimization tasks. Such problems are characterized as large scale and constrained, non-convex, non-differentiable and discontinuous, and therefore require adequate computational methods, algorithms, and software tools. The NAO conference series devotes special attention to industrial applications related to current IT hot topics such as big data, optimization and other complex numerical algorithms on the cloud, devising special techniques for supercomputing systems (e.g., a million variables and constraints for large-scale

optimization models of complex problems), and therefore, with the use of very sophisticated computer systems, large industries and organizations could benefit from the software created by computational optimization. The list of topics of the conference includes, but are not limited to: Numerical Optimization; Numerical Linear Algebra; Numerical Differential Equations; Optimal Control; Applied Mathematics; Algorithms and Software Developments; Optimization and Programming Model; Fractional Differential Equations; Challenging Applications in Science and Engineering, Technologies and Industries.

The conference NAOV-2020 was jointly organized by the Department of Mathematics, Sultan Qaboos University; Department of Mathematics and Science, German University of Technology in Oman (GUtech); and Oman Mathematics Committee. This reflects a strong collaboration of local mathematicians and the academic community in Muscat, Oman. Local and international sponsors are essential to the success of the conference, and the organizing committee would like to thank Sultan Qaboos University (SQU, Oman), A Mathematical Programming Language (AMPL, USA) and Weierstrass Institute for Applied Analysis and Stochastics (WIAS, Germany). The past NAO conferences other sponsors include Microsoft, COMSTECH (Pakistan), International Center for Theoretical Physics (ICTP, Italy), Oman Mathematics Committee, GUtech Oman, The Research Council of Oman, British Council (Oman), Bank Muscat (Oman).

NAOV-2020 was opened under the auspices of *Dr. Ali bin Saud al Bimani*, SQU Vice Chancellor. The international participants came from 27 countries across the world, and the conference talks consisted of invited and contributed speakers. The list of invited speakers were: *Adil M. Bagirov* (Federation University, Australia); *Yu-Hong Dai* (Chinese Academy of Sciences, China); >>

>> *Iain S. Duff* (STFC-RAL, UK, and CERFACS, France); *Francisco Facchinei* (Sapienza University, Italy); *David M. Gay* (AMPL Optimization, Inc., USA); *Desmond J. Higham* (University of Edinburgh, UK); *Michael Hintermüller* (Humboldt-Universität zu Berlin, Germany); *Sven Leyffer* (Argonne National Laboratory, USA); *Nezam Mahdavi-Amiri* (Sharif University of Technology, Iran); *Pammy Manchanda* (Guru Nanak Dev University, India); *Dominique Orban* (Ecole Polytechnique de Montreal, Canada); *Michael Overton* (New York University, USA); *Amiya Kumar Pani* (Indian Institute of Technology Bombay, India); *Janos D. Pinter* (Lehigh University, USA); *Cornelis Roos* (Delft University of Technology, The Netherlands); *Ekkehard W. Sachs* (University of Trier, Germany, and North Carolina State University (SAMS), USA); *Jesús María Sanz-Serna* (Universidad Carlos III de Madrid, Spain); *Michael Saunders* (Stanford University, USA); *Abulhasan Siddiqi* (Sharda University, India); *Trond Steihaug* (University of Bergen, Norway); *Philippe L. Toint* (University of Namur, Belgium); *Maria Teresa Vespucci* (University of Bergamo, Italy); *Andrew Wathen* (Oxford University, UK) and *YaXiang Yuan* (Chinese Academy of Sciences, China).

Some selected papers based on the invited talks presented at the conference *NAOV-2020* will be peer-reviewed for possible publication in an edited book of conference proceedings to be published by Springer as a series of the Springer Proceedings in Mathematics and Statistics (PROMS – website: <https://www.springer.com/series/10533>), and some selected papers from the contributed talks will be peer-reviewed for possible publication in a special issue of the following international journals: *Optimization Methods and Software – OMS* (website: <http://www.tandfonline.com/goms20>); *Springer Nature Operations Research Forum – SN ORFO* (website: <https://www.springer.com/journal/43069>); and *SQU Journal*



▲ Opening Ceremony of the Conference NAOV-2020, from the right: Professors Desmond Higham, Mehiddin Al-Baali, Iain Duff, Ahmed Al-Salman, Ahmed Al-Rawas, Ali bin Saud Al-Bimani, Nasser Al-Salti, Magda Al-Hinai, Mrs. Pinter, Janos Pinter and Adil Bagirov.

for Science (website: <https://journals.squ.edu.om/index.php/squjs/index>).

The publications from the previous NAO conference series include an edited book of Springer series on Proceedings in Mathematics and Statistics, Volume 134 (2015): <https://www.springer.com/us/book/9783319176888> and Volume 235 (2018): <https://www.springer.com/us/book/9783319900254>; special edited issues of *SQU Journal for Science*, volume 17 (2012) part 1 on Numerical Optimization: <https://journals.squ.edu.om/index.php/squjs/issue/view/44> and volume 17 (2012) part 2 on Numerical Analysis: <https://journals.squ.edu.om/index.php/squjs/issue/view/45>; volume 20 (2015): <https://journals.squ.edu.om/index.php/squjs/issue/view/50> and volume 23 (2018): <https://journals.squ.edu.om/index.php/squjs/issue/view/197>. 🌐



OPTIMA NOVEMBER 2019 IN SANTA CRUZ, CHILE: CELEBRATING THREE DECADES OF OR CONFERENCE TRADITION

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Since nearly three decades, *OPTIMA* has been the traditional bi-annual event organized by *ICHIO* (The Chilean Institute of Operational Research) jointly with a Chilean university. This event aimed to gather senior and young researchers (undergraduate and graduate students), mainly from Chile, in order to promote research activities and networking in the OR community.

OPTIMA 2019 - XIII Chilean Conference on Operations Research (<http://www.optima2019.cl/>) took place in Santa Cruz, a beautiful city located 177 km south of Santiago, Chile, from 25th to 27th of November, organized by the Industrial Engineering Department of the Universidad de Santiago de Chile (<http://www.ingenieriaindustrial-usach.cl/>).



▲ Prof. Dr. Mauricio Camargo, Keynote Speaker at OPTIMA 2019.

In this edition, **OPTIMA 2019** had the pleasure to organize two plenary sessions by OR specialists **Mauricio Camargo**, Director of the Research Team on Innovative Processes and Full Professor of Industrial Engineering School, University of Lorraine, Nancy, France, and **Safia Kedad-Sidhoum**, Co-Director of Parisian Master of Operational Research, Paris Saclay, and Full Professor of Conservatoire National des Arts et Métiers, Paris, France.

In addition, 72 research works were presented and discussed in different parallel sessions in the most important OR topics. Two student awards were granted for outstanding presentations, to **Ana Ulloa**, a postgraduate student from Universidad de la Santísima Concepción, Chile, and **Juan Carlos Piña**, a postgraduate student from Pontificia Universidad Católica de Valparaíso, Chile.

OPTIMA 2019 also included three social events: a *Welcome Reception*, a *Closing Reception* and a visit to Santa Cruz Vineyard, where a *Social Banquet* and some *tourist activities* were carried out. All social events were successful, especially the social banquet in the vineyard, an exceptional meeting point where



▲ Ana Ulloa, who received a Student Award, Prof. Dr. Víctor M. Albornó (President of ICHIO) and Prof. Dr. Óscar C. Vásquez (Chair of OPTIMA 2019), from left to right.

professional and human relationships of OR community were established in a very nice environment. 🌐



OR WORKSHOP IN POZNAN UNIVERSITY OF TECHNOLOGY, POLAND, OCTOBER 2019, AVENUES OF MODERN OR

Joanna Majchrzak <joanna.majchrzak@put.poznan.pl>; **Arkadiusz Kalemba** <arkadiusz.kalemba@put.poznan.pl>

In October 2019, Poznan University of Technology, PUT (put.poznan.pl/en) hosted astrophysics, associate professorship at the University of Florida in Gainesville Prof. Dr. Josef Kallrath (users.astro.ufl.edu/~kallrath/) in the form of a **small Workshop**. Prof. Kallrath spent three days and discussed with representatives from Faculty of Computer Science, PUT (fc.put.poznan.pl/en), and from Faculty of Engineering Management, PUT (fem.put.poznan.pl/en). During the visit, there was the time for not only scientific exchange and consultations during the official meetings, but also for social programs and exchange of general ideas on life. Before the scientific program started, a Poznan Old Town sightseeing and a visit to another city of Greater Poland, the first capital (along with Poznan) of Poland, Gniezno, took place. The broad range of scientific interests which relate Prof. Dr. Josef Kallrath with PUT researchers was considered in a "session" of meeting with Prof. Dr. hab. inż. Roman Słowiński (Faculty of Computing and Institute of Computing Science, Laboratory of Intelligent Decision Support Systems, PUT).

During his **seminar** at Institute of Computing Science, Poznan University of Technology, Prof. Dr. Josef Kallrath (University of Florida, Gainesville, FL), presented his studies on Arrangements of Circles and Spheres leading to Convex Hulls with Minimal Boundaries. The presentation was related with cutting, packing, and minimal convex hulls in 2D and 3D, with a rich diversity of illustrations and valuable remarks. During the seminar, there was the chance for discussions related with a wide scope of Prof. Dr. Josef Kallrath's research interests, on

subjects of *large-scale optimization problem, decomposition methods, column generation techniques, and hybrid methods, parameter estimation in massive datasets from astronomical surveys, combining computational geometry and mathematical optimization*. The professional experience of the visitor, especially in solving industrial problems with a broad spectrum of scientific computing methods that range from physical modelling to decision process support, as well as production planning and scheduling by mathematical optimization, contributed a lot to the discussion among the researchers from hosting Faculty of Computing, PUT, and from Faculty of Engineering Management, PUT.



▲ Reception and discussions in the "Informatics Institute" (from left to right): Prof. Dr. hab. inż. Roman Słowiński (Faculty of Computing and Institute of Computing Science, Laboratory of Intelligent Decision Support Systems, PUT) with Prof. Dr. Josef Kallrath, Prof. Dr. hab. rer. nat. Gerhard-Wilhelm Weber, and Dr. inż. Joanna Majchrzak.

Professor Josef Kallrath has an in-depth knowledge related with **binary stars** (colliding winds, eclipsing binary), mathematical modelling and optimization systems in a wide range of industries, including *energy, metals, paper, process, refineries, and telecommunication*, on solving real-world problems, which enhanced the discussions on future collaboration.



▲ Cheerful togetherness after his seminar presentation (from right to left): Administrative Director of Faculty of Engineering Management Mgr inż. Arkadiusz Kalemba, Prof. Dr. hab. rer. nat. Gerhard-Wilhelm Weber, Deputy Director of Institute of Computing Science Prof. Dr. hab. inż. Jerzy Nawrocki, Prof. Dr. hab. inż. Roman Słowiński (Faculty of Computing and Institute of Computing Science, Laboratory of Intelligent Decision Support Systems, PUT), Dean of Faculty of Engineering Management Prof. Dr. hab. inż. Magdalena Wyrwicka, with Prof. Dr. Josef Kallrath and Dr inż. Joanna Majchrzak.

Prof. Dr. Josef Kallrath's long experience as an educator, writer, and consultant guaranteed an excellent basis for mutual understanding in the diverse fields of studies gathered in the workshop audience. His contributions to *BASF SE Ludwigshafen, Germany*, to the Working Group "Real World Optimization" of **German OR Society**, and to international OR have been highly remarkable and important.

In the course of Professor Kallrath's visit at PUT, the social activities hosted by Faculty of Computing, PUT and

supported by Faculty of Engineering Management, PUT, facilitated many and innovative pathways of further discussions, exchange of information and future joint research in science and teaching, and for our *EURO* (<https://www.euro-online.org/web/pages/1/home>) and *IFORS* (<https://ifors.org/>) conferences, such as *IFORS 2020* (<http://www.ifors2020.kr/>) and *EURO 2021* (<https://www.euro-online.org/web/pages/421/activities-list>).

We would like to give a special acknowledgement

to Faculty of Computing, PUT, and to Faculty of Engineering Management, PUT, and its representatives whomade possible and facilitated the organization of *Prof. Dr. Josef Kallrath's* visit and seminar, especially, to Pro-Rector *Prof. Dr. hab. inż. Joanna Józefowska*, Director *Prof. Dr. hab. inż. Jacek Błazewicz*, *Prof. Dr. hab. inż. Roman Słowiński*, Deputy Director *Prof. Dr. hab. inż. Krzysztof Krawiec*, and Dean *Prof. Dr. hab. inż. Magdalena Wyrwicka*, respectively. 🌐



RISK ANALYSIS MEETS BAYESIAN NETWORK MODELLING IN WELLINGTON, AOTEAROA, NEW ZEALAND, FOCUSING ON RESPONSIBLE AND CULTURALLY APPROPRIATE DECISION-MAKING, NOVEMBER 2019

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Bob Cavana <bob.cavana@vuw.ac.nz>

The Australasian Bayesian Network Modelling Society and the Society of Risk Analysis Australia-New Zealand held their annual meeting jointly on 13th and 14th November 2019 in partnership with Victoria Business School (now Wellington School of Business and Government, WSBG), Victoria University of Wellington. **A/Prof. Bob Cavana** and **Prof. Vicky Mabin**, both at WSBG and long-time members and past office-holders of the Operations Research Society of New Zealand (ORSNZ), were members of the local organising committee.

The *Australasian Bayesian Network Modelling Society* (ABNMS) is a small Australian-based society with the aim to promote the understanding and use of Bayesian networks (BNs) in scientific, industrial and research applications. >>



▲ WSBG academic staff and PhD students at the poster evening. From left to right: A/Prof Bob Cavana, Richard Logan, Prof Vicky Mabin, Abeer Youssef, Dr Chris Peace, Dr Bronwyn Howell and Warren Fitzgerald.

>>BNs are probabilistic, graphical models that are well-suited to model and advance the understanding of complex problems. ABNMS had one earlier meeting in New Zealand in 2014, which despite having only 40-50 participants was attended by representatives from academia, research institutes, regulators, and private business. There were also some international participants, mainly Australians but also from Singapore and the United States of America. The impressive diversity of this meeting with a focus on the same modelling technique, applied it in very diverse areas, was never quite matched in the Australian meetings. We aimed for a similar diversity in the 2019 conference.



▲ Participants of the Conference on Risk and Decision-making held at WSBG in Wellington, New Zealand, on 13 and 14 November 2019 (Photo taken by Margaret Low, GNS Science).

The *Society for Risk Analysis Australia-New Zealand (SRA-ANZ)*, is the Australian and New Zealand chapter of the Society for Risk Analysis (SRA). The societies provide an open forum for anyone interested in risk analysis, where risk analysis is broadly defined to include risk assessment, risk characterization, risk communication, risk management, and policy relating to risk. The 2018 annual meeting in Sydney, Australia, attracted attendees from Norway, China as well as Australia and New Zealand; with representatives of universities, research institutes, regulators, and private business. SRA-ANZ also had a prior meeting in New Zealand in 2014, and the societies had a first joint meeting at the University of Melbourne, Australia, in 2017.

In 2019, the president of ABNMS, **Dr. Annemarie Christophersen** of GNS Science, and the president of SRA-ANZ, **Lee Bailey**, happened to both be based in Wellington and the societies decided have another joint meeting. We partnered with WSBG, who provided us with well-suited venue.

We selected the broad conference theme of *“Risk and Decision-Making: How different aspects of risk underpin responsible and culturally-appropriate decision-making”*. Risks and their management are an integral part of our lives in the 21st century. Identifying and assessing hazards, their uncertainties, and potential consequences is paramount for local and international organizations and governments to incorporate risk analysis into policy formulation and decision-making to protect people, the environment and the economy. The broad theme was inclusive of all topics that the individual societies had covered in the past, spanning Natural Hazards, Climate Change, Biosecurity, Chemical Management, Organisations and Governance, and Health. Each topic stream had a panel of experts to provide an international perspective and help make the sessions relevant for the current state of the field.

One focus was weaving **Mātauranga Māori** for culturally appropriate decision-making. Māori are the indigenous

Polynesian people of Aotearoa New Zealand. Mātauranga Māori is the Māoriknowledge and understanding of everything visible and invisible in the universe. **Dr Dan Hikuroa** of NgātiManiapoto, Tainui and TeArawa, The University of Auckland, gave an excellent keynote on the role of indigenous knowledge in risk analysis and decision-making.

The second keynote on “What Good Are Bayesian Networks in Modelling Risk and Decision-Making?” was given by **Marek Druzdzel, Professor Emeritus** at the School of Computing and Information, University of Pittsburgh, USA, and a founding partner of BayesFusion, a BN software company.

There were around 80 submissions across the topics, and it was a challenge to select talks to fit into two days. We used dual streaming for some sessions and introduced posters for the first time to any ABNMS or SRA-ANZ meetings. Poster presenters had the opportunity to introduce their topic in a 2-minute lightning talk in front of the plenary on the first morning. This form of introduction worked well and received great feedback. The poster session with drinks and lovely food provided a great networking opportunity in the evening.

The programme and abstracts are available online and are published by GNS Science.

Prior to the conference, ABNMS organised a two-day tutorial, which was held by **Dr. Steven Mascaro** and **Dr. Owen Woodberry** of Bayesian Intelligence. The tutorial introduced participants to the basic theory behind Bayesian networks, common software packages used in Bayesian Network modelling, methods to develop Bayesian Network models and to incorporate a range of data and expert judgement.

The conference was followed by a one-day workshop on Theory of Constraints (TOC) for Risk Analysis and Decision Making held by **Professor Vicky Mabin**. The workshop provided an overview of the suite of TOC-based thinking tools and demonstrated through practical exercises how TOC can guide analysis, decision-making and implementation.

Around 100 people from as far away as Poland, the Netherlands, Canada, the USA and South Korea, and of course many Australian colleagues attended the conference. Most participants were from New Zealand government, education and research sectors. The conference provided a great forum to exchange ideas from different viewpoints. Initial results from a post-conference survey indicate that the key motivating factor for attendance was meeting colleagues from different backgrounds.

For future meetings we will explore teaming up with the Operations Research Society of New Zealand and/or Australia. 🌐



AN AVENUE FOR OR IN INDONESIA: SIMANTAP NOVEMBER 2019 IN SIANTAR

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Gerhard-Wilhelm Weber <gerhard.weber@put.poznan.pl>

“Mathematics for Everyone” was the theme of the recently concluded *10th SIMANTAP 2019 (National Seminar on Mathematics and Its Applications)* which was held at Sapadia Hotel, Pematangsiantar (Siantar), North Sumatra, Indonesia (<https://tunasbangsa.ac.id/simantap/>).

The two-day congress which was celebrated on November 28-29, 2019, has been an activity of the *Indonesian Mathematical Society (IndoMS)*. It aimed to organize a forum for researchers, lecturers, teachers and students to exchange ideas, experiences, researches and their applications in the field of *Mathematics* and *Mathematics Education*. The seminar was initiated by the Regional Board of *IndoMS* in 2010 and is now being done annually.

Six keynote speakers and two invited speakers – all experts in the field of *Operational Research*– graced the occasion and gave their lectures on the first day of the seminar. The six keynote speakers with their presentations are as follows: **Prof. Dr. Tracey Muir** of the University of Tasmania, Australia, whose topic was on *“Mathematical Opportunities and Teachable Moments”*; **Dr. Olabode S. Adewoye** of Yaba College of Technology, Lagos, Nigeria, who discussed on *“OR: The Real Reason Why Mathematics is for Everyone”*; **Prof. Dr. Gerhard-Wilhelm Weber** of the Faculty of Engineering Management, Poznan University of Technology, Poland, and Institute of Applied Mathematics, METU, Ankara, Turkey, whose lectures were on *“RMARS Under Cross-Polytope Uncertainty - Prediction of Natural Gas Consumption with Mathematics and Artificial Intelligence”* and *“Rumor Propagation Model: OR and Numerical Approach”*; **Prof. Dr. Dorien J. DeTombe** of Delft University of Technology, Netherlands, whose lecture was on *“Prevention of Obesity: A Complex Societal Problem”*. The other two keynote speakers from Indonesia were **Dr. Syahril Efendi** the IndoMS Governor of Aceh - North Sumatra Region and a lecturer at Universitas Sumatera Utara, Medan, Indonesia, whose presentation was on *“Football Competition Information System in Indonesia With a Home and Away System”*, and **Dr. Dedy Hartama**, one of the organizers and a lecturer of Amik Tunas Bangsa who discussed on *“Model Disaster Evacuation Handle Routing Time (DEHART) for Disaster Traffic Management”*. Two Invited Speakers added to the list of OR experts. They were **Prof. Dr. Milagros R. Baldemor**– the Dean of the College of Graduate Studies of the Don Mariano Marcos Memorial State University, Philippines, who presented her paper entitled *“The 7Es Instructional Model and its Longitudinal Impact on the Mathematics Achievement of Tertiary Students”* and **Prof. Masaji Watanabe** of Okayama University, Japan, whose paper was on *“Numerical Techniques for Underwater Topographic Measurement with GPS and Echo Sounder”*.

The conference was very successful in numbers also as it was attended by ca. **800 participant**, broken down as follows: 181 paper presenters and 611 further cheerful attendees. Questions were asked by the participants to the keynote and invited speakers to clarify their queries and they were gladly answered by the speakers; this showed that the participants became satisfied with the answers given to them. Six sessions were organized due



▲ From Left to Right: Prof. Gerhard-Wilhelm Weber (Poznan University of Technology, Poland), Dr. Olabode S. Adewoye (Yaba College of Technology, Nigeria), Dr. Ahmad Ridwansyah Putra (The Main Conference Organizer), Prof. Dorien J. DeTombe (Delft University of Technology, Netherlands), Prof. Milagros R. Baldemor (DMMMSU, Philippines) and Prof. Tracey Muir of University of Tasmania, Australia) as they were given honors on stage before the start of the conference.

to the numerous participants who attentively listened to the presentations. Clarifications were given by the researchers during the *question-and-answer* portion led by the moderators assigned.

Another highlight of the event was the celebration of the 73rd birthday of the great man behind OR in North Sumatra. Branded as the *“Godfather of Operational Research in North Sumatra”* is **Prof. Herman Mawengkang**, a retired professor of Universitas Sumatera Utara (USU), Medan, Indonesia. He is an idol to lecturers and students in the field of research and an active consultant to major universities in North Sumatra. He was greeted by well-wishers with songs and gifts. He is the main reason why annual *SIMANTAP Conferences* are held during his natal day.

During *SIMANTAP 2019* also a **Skype Conference** was held with *Poznan University of Technology (PUT), Poland*, on scientific research collaboration in Human Resource Management and Analytics; discussants of that online-panel were *Assist. Dr. Magdalena Graczyk-Kucharska* and *Assist. Dr. Małgorzata Spychala* (both from Faculty of Engineering Management, PUT). Both also are members of an active team of stream organizers at our *EURO* and *IFORS* conferences on OR.

In fact, at *SIMANTAP 2019* we warmly invited to *IFORS 2020* in Seoul, South Korea, June 21-26, 2020 (<http://www.ifors2020.kr/>), and *EURO 2021*, Athens, Greece, July 11-14, 2021 (<https://www.euro-online.org/web/pages/421/activities-list>).

On November 29, the second day of the conference, while the sessions were going on in the venue, the keynote/invited speakers were toured around the scenic spots of *Pematangsiantar* including but not limited to the famous *Lake Toba* where they enjoyed a lot. They were gladly accompanied by *Dr. Ahmad Ridwansyah Putra*, the conference organizer and Rector of *Amik and Stikom Tunas Bangsa* (<https://amiktunasbangsa.ac.id/main/>) of Siantar, Indonesia.

While on tour, the speakers shared their experiences regarding the hospitality, cooperation and friendliness of the Indonesians they encountered. They were deeply appreciated as they sought to make the country their second home. 🌍



YOUNG BUSINESS AND INDUSTRIAL STATISTICIANS DISCUSS ADVANCES IN DATA SCIENCE, BUSINESS ANALYTICS AND OR, AT THE BOSPORUS IN ISTANBUL, SEPTEMBER 2019

Ozan Kocadağlı <ozan.kocadagli@msgsu.edu.tr>

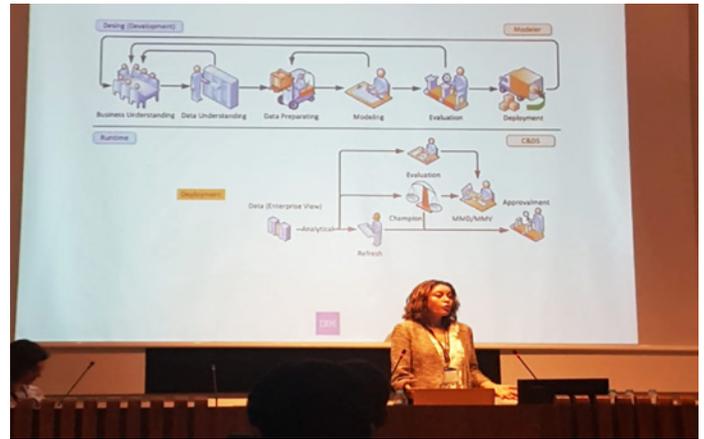
On the behalf of the *Local Organizing Committee* we were pleased to welcome the participants to our **y-BIS 2019 Conference** (<http://ybis2019.msgsu.edu.tr>): *Recent Advances in Data Science and Business Analytics* at **Mimar Sinan Fine Arts University**, Bomonti Campus, in Istanbul, Turkey, on September 25-28, 2019. This was the *fourth conference* that has been arranged and sponsored by ISBIS/y-BIS. The purpose of *y-BIS 2019* was to bring together young researchers and professionals working in **academia** and the **business world**, such as finance, medicine, insurance, energy sector, etc. *y-BIS 2019* provided many opportunities for the participants such as meeting each other, sharing scientific and professional experiences, and promoting new collaborations and international cooperation as well as interesting scientific programs and social events.

Core methodologies of the conference were from **Artificial Intelligence** and **OR Analytics**. A vast spectrum of newest aspects, chances, challenges, and relations between these areas were discussed very intensively and, as we observed, very fruitfully at *y-BIS 2019*! This discourse also addressed the upcoming forums of exchange, the OR congresses of **IFORS 2020** in Seoul, Korea, and **EURO 2021**, in Athens, Greece, with a heartily welcome.



▲ Scene from Bosphorus Boat Tour: conference organizer Ozan Kocadağlı with his Students Team.

The **scientific program** of *y-BIS 2019* consisted of **10 keynote speakers**, **8 workshops with 11 speakers**, **3 invited and 16 contributed parallel sessions with 70 speakers**, and **one poster session**. We would like to thank all the **speakers** and, in particular the **Keynote Speakers**, **Workshop and Invited Paper Session organizers** who helped greatly to enhance the conference's scientific program. More details about our speakers can be found at <http://ybis2019.msgsu.edu.tr/keynote-invited-speakers/>.



▲ Umut Satir Gürbüz, Keynote Speaker at y-BIS 2019 from IBM Turkey.

At the end of *y-BIS 2019*, all the studies presented were published as a full-paper or abstract in the *conference proceedings* with ISBN under the refereeing procedure and editorial policy of the conference. In addition, the papers accepted were directed to the five special issues of the journals: *Applied Stochastic Models in Business and Industry*, *Istanbul Business Research*, *Journal of Ambient Intelligence and Humanized Computing*, *Journal of Computational and Applied Mathematics* and *Turkish Journal of Forecasting*.

The program also included some **Social Events** such as *Welcome Reception*, *Bosphorus Boat Tour* and *Gala Dinner* which allowed the **nearly 200 participants** to get to know each other and to gain experience about Turkish culture and history and, in addition, to enjoy the *Turkish cuisine* and *hospitality*... in **Istanbul, the meeting point of two continents: Asia and Europe**.

All the studies presented, whether as full papers or abstracts, have been published in a *Conference Book*, following the conference's procedures and editorial policy. Please contact me, **Ozan Kocadağlı** (General Chair of *y-BIS 2019*), for information about the *Conference Book*. The organizers would like to thank all the institutions that provided financial support to make the organization of the workshop possible.

We express our appreciation and thanks to Mimar Sinan Fine Arts University, the International Society for Business and Industrial Statistics (ISBIS), the Central Bank of Turkey and Tam Faktoring. Lastly, I am very grateful to the *Local Organizing and Scientific Program Committees* for their superb job in organizing *y-BIS 2019*.

For more details about *ISBIS*, past and upcoming events, you can look at official website: <http://www.isbis-isi.org/>. I look forward to seeing you in forthcoming *ISI/ISBIS* scientific events! 🌐



11TH ORSN INTERNATIONAL CONFERENCE AT FEBRUARY 2020 POKHARA, NEPAL OPERATIONS RESEARCH AND SUSTAINABILITY

Dr. Bijay Lal Pradhan <bijayprad@gmail.com>



▲ [The Inaugural Session with Nepalese and Foreign delegates: (from left) Chief Guest Prof. Dr Giridhari Sharma Paudel (6th), President of ORSN Dr. Govinda Tamang (7th), Immediate Past President of ORSN Prof. Dr. Sunity Shrestha Hada (4th), Ms. Sunil Amatya (2nd from right), General Secretary of ORSN and Dr. Bijay Lal Pradhan (far right)]

The 11th ORSN International Conference (ORSN 2020) was held in Pokhara (Nepal) on February 1-2, 2020 with theme of **Operations Research: Sustainable Development** on the occasion of 13th annual day of ORSN. The ORSN Conference was organized by Janapriya Multiple Campus, a Quality Assurance and Accreditation (QAA)certified community College. The Conference brought 121 participants from four different countries (Nepal, India, China and Japan) and 68 papers in total. www.orsn.org.np.

The chief guest of the conference was *Prof. Dr. Giridhari Sharma Paudel*, Vice Chairman of Provincial Policy and Planning Commission, Gandaki Province. He discussed the resolution drawn from the conference and its implementation in the policy of the government. *Prof. Dr. Sunity Shrestha Hada* (the immediate past president of ORSN) highlighted the conference theme and its procedures.

ORSN conference executed 4 plenary Session with 9 Plenary papers. The First Plenary session had three presentation by *Prof. Dr. Gokulananda Patel*, from Birala Institute of Management and Technology, India, with topic **“Opportunities of Operations Research for Sustainability”** *Professor Dr. Ramesh Raj Kuwar* with the title **“Sustainable tourism in Nepal”**, and *Prof. Dr. Nan Zhu*, from The Western Business School, Southwestern University of Finance and Economics Chengdu, China with **“Case regarding Business Management simulations in SWUFE at China and TU at Nepal”**.

The second plenary session had three papers, with the title **“ Asia Before and After the Global Crisis”** which was presented by *Prof. Dr. Nagendra Shrestha* from Yokohama National University, Japan **“Queuing system with customers’ impatience and retention”** was presented by *Prof. Dr. Rakesh Kumar* from Shri Mata Vaishno Devi University, India and *Prof. Dr. Vikash Kumar KC*, from PN Campus, T

U with title **“Assessing the Trend of Climate Variations in Some Selected Districts of Western Nepal.”**

On 2nd February, 2020, the third plenary session was conducted with **“Stochastic Queues with Reverse Balking and Impatient Customer”** by *Bhupender Kumar Som* from Lloyd Business School, India, *Prof. Dr. Arun Bajracharya* entitled **“Exploring En-Roads, the climate change solutions simulator”** and *Janardan Ghimire* with **“the ISO 21001:2018 requirements for a management system for educational organizations”**.

ORSN also organized a workshop on Empowering Investors through financial planning for sustainable investment solution. The workshop session was conducted by Prof. Dr. Surendra Kumar Vyas, India.

In the two days, three parallel technical sessions were conducted. Altogether, there were 10 technical sessions with 59 papers. The conference program was conducted under the chairmanship of *Associate Professor Dr. Govinda Tamang*, President of ORSN. Two days pre-conference training workshop was conducted with title **“ Data analysis with R Programming”**. Thirty participants were there in the training workshop which was conducted by *Pravat Upreti*, faculty of Central Department of Statistics, Tribhuvan University. 🌐



▲ Left to right: Delegates in the opening session and Prof. Dr. G. N. Patel from BIMTEC, Delhi delivering keynote speech

WHAT TO LOOK FOR AT IFORS 2020

Natashia Boland, Program Chair

With only 4 months until the big event – the IFORS 2020 Conference in Seoul, South Korea – you may be wondering: what can I see, hear and do when I get there?

Before giving you some of the tantalizing options that will be on offer, let me first lead with the latest news.

As our IFORS President alluded to in her editorial for this issue, coronavirus has been a tragic and weighty problem for China in recent weeks, and still has the potential for serious consequences worldwide. Although it is difficult for anyone to predict the future with certainty, the IFORS leadership is optimistic that by the time IFORS 2020 arrives, on June 21st, that the situation will have stabilized, and that the conference can proceed as planned. In recognition of the challenges faced in this current period of uncertainty – especially by our Chinese colleagues, but also by other members of our world community – we have decided to extend both the Early Bird and Speaker Registration deadlines. These are now:

- Early Bird Registration Deadline: March 24, 2020
- Speaker Registration Deadline: March 31, 2020

A reminder that if you are a speaker, you must register by the deadline, otherwise your abstract will be removed from the system.

We hope that these registration deadline extensions will help all of you to plan for attending IFORS 2020 with confidence. Please rest assured that all of the organizers are continuing apace with preparations for the event!

Now I will turn to the IFORS 2020 program preparation. I am very pleased to say that our globally and scientifically diverse and enthusiastic Program Committee, with a total of 36 members, and with the collaboration of the 10-member Korean Organizing Committee, under the leadership of Prof. Suk-Gwon Chang, has put together a truly exciting line-up of highlighted speakers. We have two Plenary and 10 Keynote Speakers giving us their perspectives on the scientific developments in the field, as well as two eminent industry leaders as Invited Speakers to provide unparalleled insights into the current state of play and likely future developments of it in industry. Biographical information and the areas of expertise of the highlighted speakers can be found here: <http://www.ifors2020.kr/sub02/sub03.php>. Topics these speakers will address range from infectious diseases, disaster logistics and medical supply chains - topics on everyone's mind - to sustainability in logistics, electricity markets, renewable energy, food production, the rise of AI and machine learning, security, risk and the disruption of illicit supply chains, to mention just a few!

The Organizing Committee has also put forward a fun and enticing selection of excursion options, ranging from exploring Seoul's world-leading pop-culture icons to touring one of Korea's globally recognized electronics and IT company facilities, to see first-hand the latest electronics products and innovations in the deployment of OR technologies.

In the case of the latter tours, IFORS 2020 attendees may choose to visit either the LG display smart factory or Samsung

SDS. At the LG display factory, you will be introduced to the latest products fitted with innovative technology and will get the chance to see the optimization models implemented in the automated assembly line. At Samsung SDS, you will be able to see how OR methodologies are applied in the "Brightics AI" platform where large volumes of data is converted into informed decision making, with real time risk analysis and forecasting.

In addition to this unique opportunity to experience the industries powering daily change in the world around us, you may instead choose to experience any one of a range of cultural experiences. Seoul is a modern bustling city where one can experience old traditions, new technologies and the latest trends in pop-culture. If you are interested in immersing yourself in Korean culture, you may visit historical sites such as the Folk Village <http://www.koreanfolk.co.kr/multi/english/>, Hanok Village and Insa-dong <http://hanok.seoul.go.kr/front/eng/index.do>.

Outside of the Wednesday excursions, many alternative tour and experience options are available – see <http://english.visitkorea.or.kr/enu/index.jsp> for more information. For example, you may visit the Korean Demilitarized Zone, a strip of land running across the Korean Peninsula that serves as a buffer zone between North Korea and South Korea. Or, for a complete change of pace, experience K-pop and visit K-culture centers, a fun-filled event!

Finally, in addition to enjoying the unique experiences of Seoul and the outstanding highlighted conference speaker program, you can of course expect to enjoy great food and wonderful company as we meet each other at the Welcome Reception and Conference Banquet.

And last but not least, there are of course the scientific talks of the assembled community of Operations Researchers. Based on current abstract submissions, we are anticipating about sixteen 90-minute time slots for parallel sessions in the final program, with the number of parallel sessions ranging from 26-32.

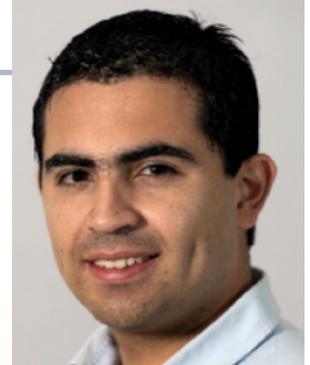
While of course all areas of OR are represented in the program, there has been particularly high levels of interest in streams that reflect new, emerging and rapidly strengthening interest, such as those on the topics of DEA (data envelope analysis) and Performance Measurement, Logistics in New Economies, Stochastic Learning and Stochastic Optimization, Multicriteria Decision Aiding, Data Analytics Meets Optimization, Discrete Optimization and Urban OR, and Meta-analytics, a new methodological concept. More traditional topics that are still vigorously represented in the program include Supply Chain Management and Scheduling with Resource Constraints, with applications of OR in the Electricity Sector and in Health Services proving popular.

I hope you are now eagerly anticipating the conference!!! Although depending on where you are, making travel arrangements may currently not be easy, I do encourage anyone who can to get in early, register as soon as possible, and make your travel plans now. Korea and IFORS 2020 awaits! 



SIX FINALISTS VIE FOR THE IFORS PRIZE FOR OR IN DEVELOPMENT 2020

Mario Guajardo <mario.guajardo@nhh.no>



Awarded at every IFORSTriennial conference since 1987, the IFORS Prize for OR inDevelopment aims to showcaseand acknowledge high quality use of OR in practice in developing countries. Past winners and finalists include works that have improved health, wellness, education, public investments and other issues in Africa, Asia and Latin America.

In this 2020 edition of the competition, the entries have been evaluated in two stages. The first one required a short summary, and the second one required a full-length manuscript describing the work in more detail. The evaluation criteria included problem definition, creativity and appropriateness of approach, MS/OR/Analytics content, stress on developmental issues, extent of involvement of local researchers and impact.

The members of the panel of judges for 2020are: Guillermo Durán and Maristela Oliveira dos Santos, from ALIO;

Janny Leung and Youn Sung Kim, from APORS; Annette Van Der Merwe and Roman Slowinski, from EURO; Mikael Rönnqvist and Song-Hee Kim, from NORAM; and Mario Guajardo, chair. This year's competitionreceived 12 entries. The process of selectionwas very rigorous and the panel of judgeselectedsixhigh quality finalists with casesfrom Chile, India, Mozambique, South Africa, Tunisiaand Vietnam. The finalists will present their works during the2020 IFORS Triennial conference in Seoul. Prizes of US\$ 4,000 and US\$ 2,000 await the first and runner-up winners, to be awarded during the conference banquet.

In the following, we are pleased to announce the six finalists of the IFORS Prize for OR in Development 2020.

DECISION SUPPORT FOR LOCATING OPTIMAL TOWER SITES FOR EARLY-WARNING WILDFIRE DETECTION SYSTEMS IN SOUTH AFRICA



Andries Heyns - University of Alabama, USA, **Warren du Plessis** - University of Pretoria, South Africa
Kevin M. Curtin - University of Alabama, USA, **Michael Kosch** - South African National Space Agency, South Africa
Gavin Hough- EnviroVision Solutions, South Africa

Early wildfire detection can effectively be achieved by systems of specialised tower-mounted cameras. Historically, the locations at which a system's towers are placed have been planned by foresters and locals with intimate knowledge of the terrain rather than by computational optimisation tools. When entering vast new territories, however, such knowledge and expertise may not be available to system planners. With the aim of maximising system visibility of smoke above a prescribed region, the process of selecting multiple tower sites from a large number of potential site locations is a complex combinatorial optimisation problem. We present a site-selection optimisation framework which may be used in such instances. Novel geographical and spatial analysis tools are implemented together with a genetic algorithm and a weighted-sum integer-linear programming approach to determine superior candidate tower-site layout alternatives. Guided by feedback from experts from the popular South African-developed ForestWatch wildfire detection system, the framework has matured into a fully-functioning decision support tool. This was recently demonstrated when the framework was implemented in the site-selection process of a four-tower camera-based wildfire detection system in South Africa's Southern Cape – a mere 60 km away from the location of arguably the most devastating wildfire in South Africa's history, which occurred in 2017.

Keywords: Decision Support Systems, Combinatorial Optimization, Location.

ECO-FRIENDLY MOBILE APPLICATION FOR THE HOUSEHOLD WASTE COLLECTION AND TRANSPORTATION PROBLEM: CASE OF THE CITY OF SOUSSE



Haifa Jammeli - University of Tunis\NORMASYS, France, **Masri Hatem** - University of Bahrain, Bahrain
Fouad Ben Abdelaziz - Neoma Business School, France, **Mejdi Argoubi** - Institut Supérieur de Gestion de Sousse, Tunisia

This paper's aim is to develop a model for the household waste collection and transportation problem in the city of Sousse, one of the largest cities in Tunisia. Several vehicles with a finite capacity are located at the depot. The vehicles must collect the waste accumulated in all bins. The waste is then delivered to a transfer center, before vehicles return to the depot. The proposed model determines the routes of the vehicles and the number of bins to be assigned to each potential location, while minimizing the collection costs and the environmental impact. The problem can be considered as a bi-objective optimization problem, as cost minimization will be ensured by the optimal assignment of the determined minimum number of bins. We also consider the stochastic aspect of population size, which is supposed to follow a normal distribution. Our model is then a stochastic bi-objective programming model. A solution is obtained with reasonable computational effort using a hierarchical approach consisting of two stages as "cluster-first route-second". In the first stage, a set of n locations of bins is assigned into k disjoint clusters using the K-means clustering algorithm. In the second stage, a certainty equivalent program to the bi-objective stochastic program is proposed, based on a chance-constrained, recourse and a goal programming approach. The model is tested and implemented using real data from the municipality of Sousse. The study shows that our model leads to lower environmental impact and an almost 38% reduction in the economic costs.

Keywords: Stochastic Models, Transportation

SCHOOL CHOICE IN CHILE



José Correa - Universidad de Chile, Chile, **Rafael Epstein** - Universidad de Chile, Chile, **Juan Escobar** - Universidad de Chile, Chile, **Ignacio Rios** - Stanford University, USA, **Bastián Bahamondes** - Universidad de Chile, Chile, **Carlos Bonet** - Columbia University, USA, **Natalie Epstein** - Universidad de Chile, Chile, **Nicolás Aramayo** - Universidad de Chile, Chile, **Martin Castillo** - New York University, USA, **Andrés Cristi** - Universidad de Chile, Chile, **Boris Epstein** - Universidad de Chile, Chile, **Felipe Subiabre** - Universidad de Chile, Chile

We report the design and implementation of the newly established school choice system in Chile, where over 274,000 students applied to more than 6,400 schools. The Chilean system presents unprecedented design challenges that make it unique. On the one hand, it is a simultaneous nationwide system, making it one of the largest school choice problems worldwide. On the other hand, the system runs at all school levels, from Pre-K to 12th grade, raising at least two important issues: (1) the system needs to guarantee their current seat to students applying for a school change, and (2) the system has to favor the assignment of siblings to the same school. As in other systems around the world, we develop a model based on the Deferred Acceptance algorithm. The algorithm deals not only with the aforementioned issues, but also with further practical features such as soft-bounds and overlapping types. In this context, we analyze new stability definitions, present the results of its implementation and conduct simulations showing the benefits of the proposed innovations.

Keywords: Game Theory, OR in Education, OR in the Public Sector

A LIGHT-TOUCH TOOL FOR OPTIMAL VACCINE DISTRIBUTION IN MOZAMBIQUE



Larissa P.G. Petroianu - University of Washington, USA, **Zelda B. Zabinsky** - University of Washington, USA, **Mariam Zameer** - VillageReach, USA, **Yi Chu** -University of Washington, USA, **MamizaM. Muteia** - VillageReach, Mozambique, **Mauricio G.C. Resende** -University of Washington, USA, **Aida L. Cohelo** -VillageReach, Mozambique, **Jiarui Wei** - University of Washington, USA, **Turam Purty**- University of Washington, USA, **Abel Draiva**- VillageReach, Mozambique, **Alvaro Lopes** - VillageReach, Mozambique

Planning vaccine distribution in rural and urban poor communities is challenging, due in part to inadequate vehicles, limited cold storage, road availability, and weather conditions. The University of Washington and VillageReach jointly developed and tested a user-friendly, Excel spreadsheet-based optimization tool for routing and scheduling to efficiently distribute vaccines and other medical commodities to health centers across Mozambique. We will describe the tool and the process used to define the problem and obtain feedback from users during the development. The distribution and routing tool, named Route Optimization Tool (RoOT), uses an indexing algorithm to optimize the routes under constrained resources. Numerical results are presented using three realistic datasets. RoOT can be used in routine or emergency situations, and may be easily adapted to include other products, regions, or logistic problems.

Keywords: Developing Countries, Transportation, Routing

JALTANTRA: IMPACTING THE PRACTICE OF RURAL WATER NETWORK DESIGN IN INDIA



Nikhil Hooda - IIT Bombay, India, **Om Damani** - IIT Bombay, India, **Ashutosh Mahajan** - IIT Bombay, India

JalTantra has changed the practice of rural piped water network design in and beyond the state of Maharashtra, India. Existing tools for water network design look at only pipe diameter optimization and are either difficult to use because of hardware requirements and licensing costs or have limited capabilities developed in the 1990s. Real world networks however also contain components such as tanks, pumps and valves whose parameters require a careful selection. JalTantra takes a deterministic and optimal approach to the overall design and is developed as a free to use web application. The problem is modeled as a Mixed-Integer Linear Program. The simultaneous consideration of pipes, tanks, pumps and valves results in a complex model for network sizes of practical importance. The time taken to optimize an example 150 node network was 40 minutes and a 200 node network could not be solved within 24 hours. Several reformulations were introduced to produce a much tighter model, resulting in the two networks taking just 5 and 70 seconds respectively. Developed in partnership with water supply engineers, JalTantra is an example of how the university can help government departments in carrying out their developmental duties. JalTantra has been successfully deployed by government engineers for designing rural water networks and due to its minimum cost design, saves the government 100s of millions of Indian Rupees each year. It is now part of the training curriculum of these engineers.

Keywords: Water Management Applications; Developing Countries; Integer Programming

OPTIMAL INVESTMENT STRATEGIES TO MINIMIZE FLOOD IMPACT ON ROAD INFRASTRUCTURE SYSTEMS IN VIETNAM, GCRF-OSIRIS



Maria Paola Scaparra - University of Kent, UK, **TrungHieu Tran** - Brunel University London, UK, **Siao-LeuPhouratsamay** - University of Bordeaux, France, **Thinh Dang**-Vietnam Institute of Meteorology, Hydrology and Climate Change, Vietnam, **PhùngChính** - Vietnam Institute of Meteorology, Hydrology and Climate Change, Vietnam, **Hiep Nguyen** - Vietnam Academy of Science and Technology, Vietnam, **Graham Adutt**- University of Kent, UK, **Dang Phuong** - University of Kent, UK, **Chinh Ngo** - Asian Management and Development Institute, Vietnam, **Pham Chung** - Center of Urban and Rural Transport, TDSI, Vietnam

Development challenges such as urban flooding in Southeast Asia are typically addressed with approaches drawing on environmental science, cost-benefit analysis and local political expediency. The GCRF-OSIRIS Project, funded by the Global Challenge Research Fund through the British Academy, introduced a novel approach to identify cost-efficient measures to mitigate the impacts of urban flooding by integrating OR with transport economics, climatology, hydrology and social science. In close partnership with Vietnamese academic and government agencies, the project created a scenario-based, multi-period, bi-objective Mixed Integer Linear Programming model to minimize infrastructure damage and traffic congestion in central districts of Hanoi. A GRASP metaheuristic was developed to solve large-scale instances of the problem and the overall approach was embedded into a Decision Support System to enable planners and policy makers to use the optimisation tool. Using a set of drainage mitigation measures provided by Vietnamese stakeholders and flood maps generated by researchers at the Vietnam Institute of Meteorology, Hydrology and Climate Change, the optimisation tool was applied to generate a 20-year plan of investments. More than half of the total reduction in congestion and damage was found to be achievable with less than 25% of available budgets. The project has catalysed interest in Vietnam and in neighbouring countries to develop capacity in OR to address development challenges.

Keywords: Developing Countries, Sustainable Development, Integer Programming

BOOK REVIEW

Section Editor: **Gerhard-Wilhelm Weber**

NONLINEAR OPTIMIZATION A CONTRIBUTION TO EDUCATION AND RESEARCH BY A “KEY TECHNOLOGY” OF OR ANALYTICS

Aragón, F.J., Goberna, M.A., López, M.A., Rodríguez, M.M.L.,

This new text book by the team, in fact, research team, of *F.J. Aragón, M.A. Goberna, M.A. López and M.M.L. Rodríguez*, is a valuable contribution to one of the core domains of Operational Research: **Optimization**, its theory, methods and applications. This “key technology” fosters our processes of culture and civilization since Antiquity and, since the first Industrial Revolution, it is a “motor” that drives ahead our modern industries, economies, societies and daily lives.

To be more specific, this book is situated in the interface between (i) Nonlinear and continuous optimization **Education**, with an emphasis on its computational and numerical sides, and the rapidly growing fields of (ii) Mathematical Modeling

and other applied areas, herewith preparing the way to **Research** progress in (iii) Data Mining, Analytics, Statistical Learning, Machine Learning, Deep Learning and, eventually, Artificial Intelligence with its mathematical foundations, that are helpful and needed. We recall the enormous boost which the invention of the optimization *Method of Least Squares* with the related *Normal Distribution* by *Carl Friedrich Gauss* brought to the rise of Statistics and, eventually, to all the fields aforementioned. That, for example, celebrated Machine Learning is not mainly about “machines” of any technical provenance, but about Data - Big Data, and stated by Optimization problems and solutions - by OR, more and more academics and non-academics realize worldwide...

This book is theoretically rigorous, practically relevant and pleasantly motivating the reader. Based on it, in forthcoming years, the youth of *OR*, applied mathematics and other applied disciplines can be educated and trained in improved ways. Moreover, further inquiries can be made and real-world applications performed, in the vast growing field of studies at the micro and macro scales everywhere, for the sake of future **Industries 4.0**, of nature and environment, and the living conditions of humankind.

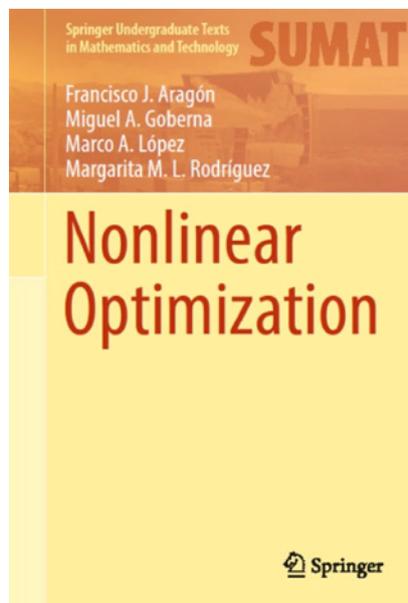
This novel monograph is particularly useful for upper-level undergraduate students of mathematics and statistics, and for graduate students of *OR* and *MS* (Management Science). It can also serve as an introduction into optimization for *OR-MS* researchers and practitioners with yet little knowledge in optimization. Indeed, the authors refrain from sophisticated tools of convex analysis (like Rockafellar subdifferential or Fenchel–Moreau conjugate function) and nonsmooth analysis (like Clarke and Mordukhovich subdifferentials). The book includes some basic theoretical results and many well-selected and representative numerical methods for programs with or without constraints, some of them “derivative-free” - with no analytic differentiation needed.

The authors enjoy a high reputation, especially, due to their powerful research work during many decades, e.g., in *Semi-infinite Optimization* (where infinitely many constraints are allowed) and related subjects. Their research work includes scientific discussions with scholars and the youth from all over the world. Those discussions have taken place at many conferences of various formats, e.g., meetings organized by *IFORS*, *EURO*, or by *EURO Working Group on Continuous Optimization (EUROPT)* which they served for twenty years. So this book is another academic merit of the authors, established on their great experience in research and education. Strong scientific foundations allowed the authors for a clear and pleasant way of expression.

This, in its way, unique monograph offers to the reader a number of benefits, such as: (i) It contains exercises with selected solutions, (ii) It features model building, real problems, and applications of optimization models, (iii) It provides numerical approaches to solve programs of nonlinear optimization.

The six chapters of the book are these: *Chapter 1*: Preliminaries, **Part I**: *Chapter 2*: Analytical Optimization, *Chapter 3*: Unconstrained Optimization, *Chapter 4*: Convex Optimization, **Part II**: *Chapter 5*: Unconstrained Optimization Algorithms, *Chapter 6*: Constrained Optimization, and *Solutions to Selected Exercises* are proposed at the end.

This new textbook concentrates on model building, real-world problems, and applications of optimization models to natural and social sciences. Organized along the *Parts I* and *II*, it can be used in *OR Education* for university courses on both convex and nonconvex optimization. Definitions, proofs, and numerical methods are well exemplified and



Nonlinear Optimization by Aragón, F.J., Goberna, M.A., López, M.A., Rodríguez, M.M.L., Springer Undergraduate Texts in Mathematics and Technology. Cham: Springer (ISBN 978-3-030-11183-0/hbk; 978-3-030-11184-7/ebook). xiv, 350~p. (2019).

illustrated; every chapter offers thoughtful and appealing exercises. These exercises make appeal *lively* and *understandable* some fundamental theoretical results about optimality and duality, algorithmic methods with or without constraints, and derivative-free optimization (DFO). Solutions proposals are provided as well. Applications to theoretical results and numerical methods are highlighted to help the reader in learning the approaches and methods.

This monograph is based on the contents of two undergraduate courses taught at the *University of Alicante*, Spain. Before these 2 courses are stated here, a course on *Linear Programming (LP)* is provided. As this knowledge is not expected in the main body of the book, a reader may skip the LP course. Another freedom given to the reader comes from the independence between *Parts I* and *II*, except for their “preliminary” *Chapter 1*. As in Asian restaurants sometimes the guests are informed, or warned, about the spiciness of a meal by some red chili icons in the menu, those sections and subsections which are mathematically harder than the others are

marked with an asterisk (*). These parts may be skipped as well if the reader has a limited background or time is too short.

Part I consists of *Chapters 2-4*, focusing on the **analytic** calculation of **global** minima as they are usually required in *OR*, engineering and economics, etc., and of **local** minima as required in natural sciences where equilibrium situations correspond to local minima or critical points. *Chapters 1-2* contain basic ingredients for the calculus of both *local* minima (optimality conditions for differentiable functions) and *global* minima (coercivity and convexity) for unconstrained optimization problems. *Chapter 3* provides closed formulas for unconstrained optimization programs from different areas, whereas *Chapter 4* deals with unconstrained and constrained convex optimization problems. For those convex programs, local and global minima *coincide*.

Part II is devoted to the cases where solutions cannot be analytically obtained but numerical computation of local optima are needed; it is composed of *Chapters 5-6*. First, *Chapter 5* deals with standard algorithms for unconstrained optimization, like *steepest descent* and *Newton’s methods*, their variants and combinations, such as *trust-region*, *Gauss-Newton* and *Levenberg–Marquardt* methods, and other *gradient-based procedures*, such as those using conjugate directions, e.g., conjugate gradient and quasi-Newton methods. Local or global **convergence** of these methods are discussed, along with their **rates** of convergence (linear, superlinear, and quadratic). This chapter also includes an introduction to DFO methods - *no derivatives* given here.

Eventually, *Chapter 6* first introduces the *so-called penalty* and *barrier methods*, addressing the numerical solution in constrained optimization by applying the codes explained in *Chapter 5*. They base on a conversion of a constrained problem into a sequence of unconstrained ones.

>> The second part of *Chapter 6* is devoted to the optimality conditions for constrained optimization problems, with equality or inequality constraints or both. The importance of *Constraint Qualifications*, with their geometric “manifold” meaning for the constrained set, is underlined since they yield *necessary optimality conditions* which are useful to find *stopping rules*. Eventually, the authors show how optimality conditions naturally lead to *Sequential Quadratic Programming*, when *Newton’s method* is applied for solving the corresponding system of equations.

This monograph does not intend to provide an exhaustive overview of the whole optimality theory and optimization techniques. But if a reader wishes to get a deeper knowledge about related topics, he or she is guided to visit a list of references given at the end of the book. What is more, for any reader interested in **OR history** of optimization, another list is offered by the authors.

This textbook only assumes basic knowledge of differential and matrix calculus. All the main concepts, algorithms and proofs are didactically supported by appealing figures and their careful explanations. The book pays special attention to model building and validation of real problems, and emphasizes the **practical** advantages of obtaining good reformulations of optimization problems. It presents important applications of optimization models to natural and social sciences, engineering and data science. It provides rigorous optimality conditions; existence and uniqueness of optimal solutions are analyzed in terms of convexity and coercivity. **Dual** problems (“*the other side of the coin*”) are introduced in order to receive lower bounds, sensitivity information (“*what if?*” questions), and stopping rules of *primal-dual* algorithms. The book provides an accurate and concise description of core concepts to algorithmically solve nonlinear optimization programs. Five assignments for *Laboratory Sessions* of 2 hours are offered. This book has been thoroughly *tested*; many years of undergraduate courses demonstrated its success with preliminary versions even. The exercises are selected to gently push the reader to a deeper understanding of the main topics. The detailed solution proposals for “harder” exercises are another advantage of this work.

Apparently, this book is clearly and well structured, analytically deep, well exemplified, beautifully illustrated, and written with great expertise, foresight and taste.

In the future, refinements and extensions in analytic, theoretical foundations and algorithmic techniques may be considered by the authors and within the academic community, prepared, supported and inspired by this book. These could be made in the form of articles and monographs, and in terms of *Singularity and Morse Theory*, of *Robust Optimization*, *Calculus of Variations* in new geometries, *Optimal Control*, *Stochastic Optimal Control*, and of *Discrete-Combinatorial* elements such as *thresholds and cutting points*, *disruptions* and *regime switching*, *hybrid systems*, *collaborative games* and *stochastic games*.

Such future advances can foster progress in natural sciences and high-tech, in close conjunction with **OR** and its *analytics* and *decision making* links with Management, Industries k.O, Economics and Finance, Actuarial Sciences and Pension Fund Systems, Bio-, Neuro- and Medical Sciences, Environmental, Geo- and Earth-Sciences, Societal and Developmental Sciences – with their rapidly growing number of theoretical challenges and real-world applications. For all of these charismatic areas, modern **OR** is not just a field of fruitful application, but also an invaluable source of motivation and inspiration, and a driving scientific “motor” into the future.

After all these details we conclude with something to listen and cherish, too. Let us return to *Carl Friedrich Gauss* and his student - a legend as well, *Bernard Riemann*, looking with them at optimization and, as we say, **OR Analytics** of Data Mining, Machine and Deep Learning, and AI, in one beautiful frame together with the *Number Theory* of “primes”, its use in modern encryption and security systems, and *Non-Euclidean Geometry* as “the mathematics” of *Albert Einstein’s General Theory of Relativity*, with its exciting and practical contributions to our world. Now let us enjoy a few broadcasts at *BBC Radio 4*, with *Melvyn Bragg*, *Marcus du Sautoy* and others: <https://www.bbc.co.uk/sounds/play/b09gbnfj>, <https://www.bbc.co.uk/sounds/play/b00ss0lf> and <https://www.bbc.co.uk/programmes/b00ss1jg>. 🌐

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