16th ESICUP Meeting

ITAM, Mexico, April 8-12, 2019

Organization

EURO THE ASSOCIATION OF EUROPEAN OPERATIONAL RESEARCH SOCIETIES

ITAM INSTITUTO TECNOLÓGICO AUTÓNOMO DE MÉXICO

SMIO SOCIEDAD MEXICANA DE INVESTIGACIÓN DE OPERACIONES

EWG ESICUP CUTTING AND PACKING

Table of Contents

Local Organizing Committee:

Marta Cabo Nodar (Chair), ITAM

Program Committee:

Julia Bennell (chair), University of Leeds

José Fernando Oliveira, University of Porto

Ramón Alvarez-Valdes, University of Valencia

Tony Wauters, KU Leuven

Francois Clautiaux, Université de Bordeaux

Michele Monaci, University of Bologna

Antonio Martinez-Sykora, University of Southampton

Organised by:

ESICUP – EURO Special Interest Group on Cutting and Packing

SMIO – Sociedad Mexicana de Investigación de Operaciones

ITAM – Instituto Tecnológico Autónomo de México

Welcome

Dear Friends, Welcome to the 16th Meeting of ESICUP - The EURO Special Interest Group on Cutting and Packing. Since its formal recognition as a EURO Working Group in 2003, ESICUP has run a series of annual meetings which have successfully brought together researchers and practitioners in the field of cutting and packing. Previous meetings have been organized in Wittenberg (Germany), Southampton (United Kingdom), Porto (Portugal), Tokyo (Japan), L'Aquila (Italy), Valencia (Spain), Buenos Aires (Argentina), Copenhagen (Denmark), La Laguna (Spain) and Lille (France), Beijing (China), Portsmouth (United Kingdom), Ibiza (Spain), Liège (Belgium), Zoetermeer (Netherlands) and the 16th meeting in Mexico City (Mexico).

Once again, this meeting will serve as an instrument for the development of research and the dissemination of knowledge in our field. Moreover, this meeting will be a vehicle to disseminate knowledge and expertise in cutting and packing across the Atlantic. This year the conference has been supported by a knowledge transfer grant funded by the UK Royal Society to facilitate knowledge transfer into Mexico. As a result, we have eight tutorials from internationally recognised experts during the meeting and we would like to give our sincere thanks to Ramon Alvarez, Julia Bennell, Francois Clautiaux, Claudia Lopez, Michele Monaci, Jose Oliveira, Franklina Toledo and Tony Wauters.

We are delighted to be holding the meeting at ITAM, Mexico City. ITAM is a private, secular, non-profit Mexican institution of higher education. Its mission is to contribute to the comprehensive education of students and to the development of a freer, more just and more prosperous society. In order to carry out its teaching and research objectives, ITAM aspires to the highest levels of academic excellence, while supporting a diversity of ideas and a community that respects ethnic, cultural, and religious differences. The Department of Mathematics teaches its undergraduate student with a focus in applying mathematical models to solve decision problems. This ESICUP meeting has received funds from the Mexican Operations Research Society (SMIO) and the Mexican Mathematical Society (SMM), and we would like to thank both for their support.

Mexico City is one of the most populated cities in the world. Located on mountains, the city is 2.2 km above sea level. Mexico City has the largest amount of museums in the Americas and the second largest amount in the world, after London. Chapultepec's park is twice the size of New York's Central Park and there are at least eight important archeological zones in Mexico City and surroundings. In addition, Mexico City is best known worldwide for its hospitality and its people's warmth. Its people (commonly called "chilangos") will always be ready to welcome you with the biggest and kindest smile. We do hope you can feel this hospitality during the ESICUP meeting. We wish all of you a successful conference and a very pleasant stay in Mexico.

Julia Bennell
University of Leeds
Program Chair

Marta Cabo Nodar
ITAM
Local Organizer Chair

Information for Conference Participants

MEETING VENUE

The 16th ESICUP Meeting will be held at ITAM, Mexico City, Mexico. This year's workshop is extended to include 9 tutorials by internationally recognised researchers in cutting and packing.

Address:

ITAM Sta Teresa

Av, Camino de Sta. Teresa 930,

Col. Héroes de Padierna, 10700

Magdalena Contreras,

Ciudad de México (CDMX)

REGISTRATION

The registration desk will be located in the meeting venue where you will collect your name badge and registration pack for the event. Registration will be open from 8.30am to 9.00am, April 9, 2019 and during session breaks.

YOUR NAME BADGE

You should wear your name badge at all times during the event. It is your admission to the venue (includes coffee breaks and lunch).

NOTES ON PRESENTATION

- **Equipment**
  The conference room is equipped with an overhead projector and a laptop computer will be provided. We suggest that you bring your own computer and/or transparencies as a backup.

- **Length of Presentation**
  25 minutes for each talk, including discussion. Please note that we are running on a very tight schedule. Therefore, it is essential that you limit your presentation to the time which has been assigned to you. Session chairpersons are asked to ensure that speakers observe the time limits.

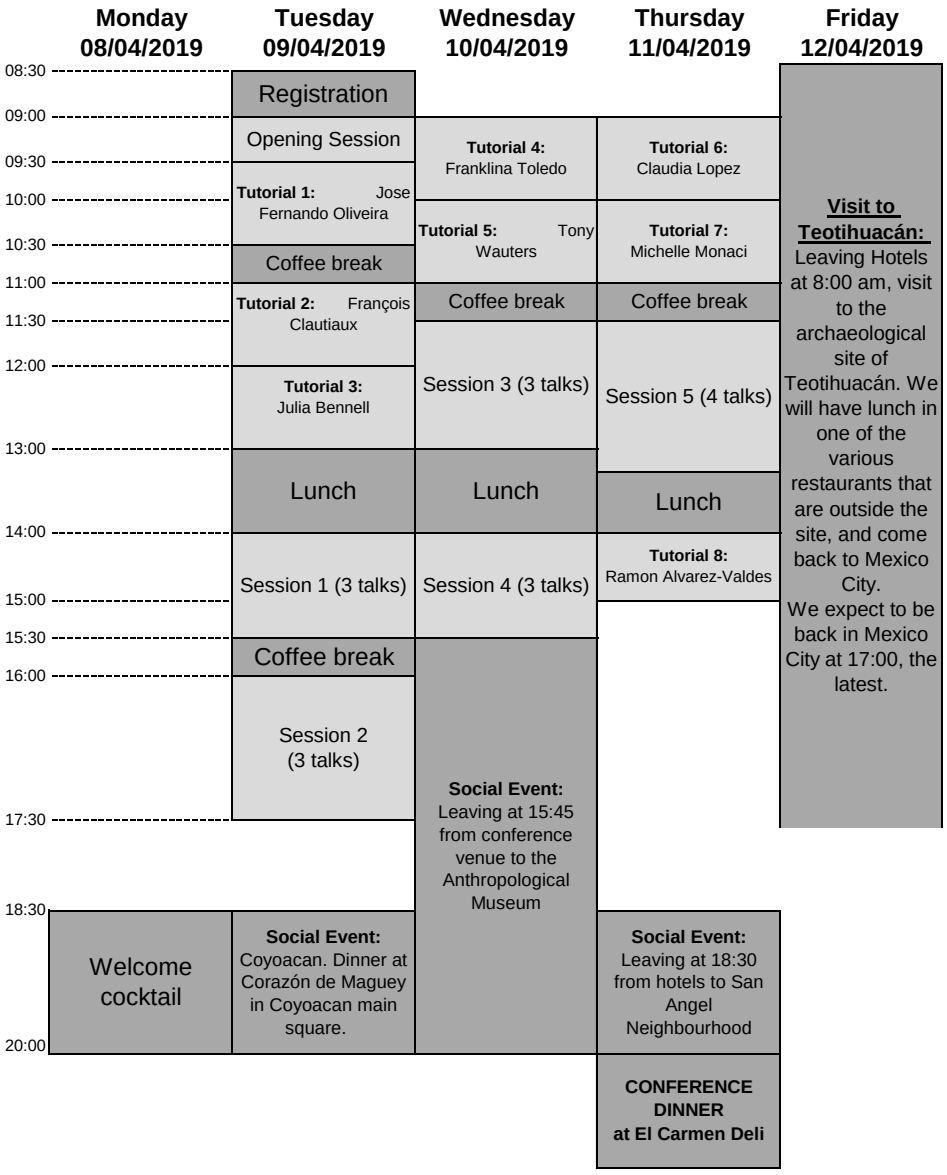
INTERNET ACCESS

Further details on how to access wireless network at the conference venue will be given at registration.

DIETARY, MOBILITY AND OTHER REQUIREMENTS

Please let the registration desk know if you have any additional special requirements.

Program Overview



Scientific Program Schedule

Tuesday, april 9th

9:00 – 9:30

Opening Session

Welcome Address

14:00 – 15:30

Session 1 *Chair: Marta Cabo Nodar*

1.1 – A binary programming model for the quasi-polyomino tiling problem
Marcos Okamura Rodrigues and Franklina Maria Bragion de Toledo**

1.2 – "An Adaptive Large Neighbourhood Search for Optimising the LEGO Construction Problem"
Torkil Kollsker, Thomas Stidsen*, Mathias Stolpe**

1.3 – "Cuts for Bin-Packing Problem using Benders Decomposition Algorithm"
Eleazar Gerardo Madriz Lozada, Yuri Tavares dos Passos*, Lucas Carvalho Souza**

16:00 – 17:30

Session 2 *Chair: Françcois Clautiaux*

2.1 – Dynamic integrated multi-item order sizing and packing
Patrick Engelsberg, Martin Grunewald† and Thomas Volling‡*

2.2 – An integrated cutting stock and scheduling problem
Lemos, Felipe Kesrouani, Cherri, Adriana Cristina*, Araújo, Sílvio Alexandre* and Yanasse, Horácio†*

2.3 – Packing Clusters of Objects
I. Litvinchev, J.A. Marmolejo†, A. Pankratov‡, T. Romanova‡*

Wednesday, april 10th

11:30 – 13:00

Session 3 *Chair: Claudia Lopez*

3.1 – "A matheuristic for the 3D Single Large Object Placement Problem with stability constraints"
Everton Fernandes Silva, Aline Leão†, Franklina Maria Bragion Toledo†, Tony Wauters**

3.2 – One-dimensional Bin packing Problem: An experimental study of instances difficulty
*Marcela Quiroz-Castellanos**

3.3 – Use of a Mechanical Model to Predict Dynamic Stability Metrics in the Container Loading Problem for Inclusion in Optimization Strategies
Juan Martínez-Franco, Daniel Cuellar-Usaquen*, Edgar Céspedes-Sabogal*, David Alvarez-Martínez**

14:00 – 15:30

Session 4 *Chair: Franklina Toledo*

4.1 – Column Generation based Heuristic Algorithms for the Two-dimensional Two-stage Guillotine Cutting Stock Problem
Sue-Jeong Kwon∗ and Kyungsik Lee∗

4.2 – MULTI-START HEURISTIC FOR THE TWO-DIMENSIONAL GLASS CUTTING PROBLEM OF THE SAINTGOBAIN GLASS FRANCE COMPANY (ROADEF/EURO CHALLENGE 2018)
Germán Fernando Pantoja Benavides, David Álvarez-Martínez**

4.3 – An archaeological irregular packing problem
J.A.Bennell, M. Cabo Nodar†, C. Lamas Fernandez*, A. Martinez-Sykora**

Thursday, april 11th

11:30 – 13:15

Session 5 *Chair: Tony Wauters*

5.1 – Solution method for the two-dimensional cutting stock problem with usable leftovers
Douglas Nogueira do Nascimento, Adriana Cristina Cherri†, José Fernando Oliveira‡*

5.2 – A sim-heuristic approach for the 3D irregular packing problem
Germán Fernando Pantoja Benavides, David Álvarez-Martínez**

5.3 – Nesting packing of circular objects
Igor Litvinchev, J.D. Mosquera-Artamonov*, Lucero Ozunab†*

5.4 – Metaheuristics to Solve Grouping Problems: A Review
Octavio Ramos-Figueroa, Marcela Quiroz-Castellanos**

Social Program

- **Welcome Cocktail**
  To welcome you to the 16th ESICUP meeting, we have prepared a welcome cocktail at ITAM Rio Hondo (`https://www.google.com/maps/place/ITAM/@19.3450908,-99.2010739,18z/data=!3m1!4b1!4m5!3m4!1s0x85d200057116a1d1:0xeb89056e16e93b4f!8m2!3d19.3450908!4d-99.2001039`). Note that this is a different location from where the talks will take place.

  Cocktail begins at 18:30. A registration desk will be available.

  Note that on this day, we cannot provide transport, however, asking for a taxi from your hotel or an uber is always a safe option. We do not recommend taxis from the street.

- **Tuesday 9th of April**
  A coach will pick participants from the hotels at 18:30 and go to Coyoacan neighbourhood. This is a nice colonial area, with bars, restaurants, and traditional shops, that you can enjoy before dinner. We are selecting one of the many restaurants around to have dinner, but feel free if you prefer to dine somewhere else around the area.

  But don't worry!! You don't need to make a decision right now!! On the very day, I will be asking you to sign your name down, so we can book the restaurant.

- **Wednesday 10th of April**
  This day as we are planning less talks, we will leave the conference venue at 15:45 and lead to the Anthropological Museum. The museum closes at 19:00, so I expect you'll have time to get a good glimpse of the main exhibitions.

  Tickets to the museum will be purchased on site. They cost 70 MXN approx 3.5 Euros.

  Once the museum closes, our bus will take us to a Taquería, a typical mexican restaurant where we can enjoy tacos (the best-known mexican dish) as well as other mexican dishes.

- **Thursday 11th of April: Gala Dinner (included with registration)**
  After the last talks of this meeting, we will celebrate with our traditional gala dinner. The restaurant is located San Angel Neighbourhood, a nice traditional area with lots of arts and crafts shops. Thus, to make some last minute shopping or just browse the many mexican arts and crafts, we are leaving from the hotels at 18:30. Dinner will start at 20:00 at El Carmen Deli (`http://www.elcarmendeli.com/`)

  To provide you with a better service, please fill the following form with your choices for the dinner, before the end of the week, so the restaurant can prepare your meal in advance:

  `https://forms.gle/gcmpphuC43soYH346`

  In this form, please state whether you are vegetarian or if you have any food allergies, so we can take that information into account also at lunch time.

- **Friday 12th of April**
  For those who are willing to explore an ancient Aztec City we are planning a trip to Teotihuacan.

An ancient city, which has been very well preserved, and has plenty of history.

We will be leaving from the hotels at 8:00 am, and have lunch in one of the many restaurants that are outside the site. We expect to be back in Mexico City around 18:00. Tickets are 70 MXN approx 3.5 Euros and will be bought on site.

For those that are thinking on coming to this day trip, please bring a cap, comfortable shoes, and sunscreen lotion, since it is expected to be very sunny and there are no shades along the way. If you need more information about the site, please visit: `https://adventurousmiriam.com/day-trip-teotihuacan-pyramids-mexico/`

Tutorials

Ramon Alvarez-Valdes

Title: Solving routing problems with realistic packing constraints

Abstract: In this talk, I will first review the work on Container Loading Problems with practical constraints developed in recent years, and then I will show how these constraints have been introduced when solving combined routing/packing problems.

Ramon Alvarez-Valdes is a Professor at the Department of Statistics and Operations Research, University of Valencia, Spain. He is interested on Combinatorial Optimization problems, such as Project Scheduling, Machine Scheduling, Timetabling, Cutting and Packing, and Container Terminal Operations. He has developed theoretical and applied research in these fields, published papers and participated in research projects funded by companies and by public research institutions.

Julia Bennell

Title: Handling the geometric constraints in cutting and packing problems

Abstract: One of the defining features of cutting and packing problems is the geometric constraints where small items cannot overlap and must be contained within the large object. Handling these constraints effectively has a critical impact on the efficiency of an solution algorithm and can dictate the algorithm design. In this talk I will review the range of methodologies for handing geometry, provide some simple examples and discuss the strengths and limitations.

Julia Bennell is Prof of Management Science at Leeds University Business School. She has been an active researcher in cutting and packing problems for over 20 years and published articles in two and three dimensional problems largely focusing on irregular shape packing. She has been a member of the ESICUP committee since 2004 and the co-ordinator of the group since 2017.

François Clautiaux

Title: Extended formulations for packing problems

Abstract: In this tutorial, we show how so-called "extended formulations" allow to solve efficiently several classes of cutting and packing problems. One one hand, these formulations have excellent theoretical properties. On the other hand, they typically have an exponential number of variables/constraints. Several advanced techniques are thus needed to solve them, including iterative column-and-row generation, and iterative aggregation methods.

François Clautiaux is professor in the mathematics department of University of Bordeaux. His main focus is on integer programming methods for solving combinatorial optimization problems, including cutting and packing problems, from both theoretical and practical points of view.

Claudia López

Title: A glance through the packing problem

Abstract: The goal of this tutorial is to give a general view of the packing problem. We are going to start with a introduction to the problem, followed by applications of the packing problem and, finally we will present of the different methods that have been used to find the best solution.

Claudia López obtained her bachelor degree in Actuarial Science at the Faculty of Science in 2016; UNAM, Mexico City. The degree was obtained with a written work, the subject of study was network flows problems using the painted network algorithm.

In 2008 she obtained a Master degree in Operational Research at Graduate School of Engineering, UNAM, Mexico City. The drgree was obtained with a written work, the subject of study was an introduction to concave minimization.

In 2013 Claudia obtained her PhD In Operational Research at Brunel University, London, UK. The thesis was about the 2-dimensional packing problem. Since May 2013 she is a full time associate professor at the Faculty of Science; UNAM, Mexico City.

Michele Monaci

Title: Knapsack problem and variants

Abstract: The knapsack problem is one of the most famous problems in the Combinatorial Optimization area. Though the knapsack is NP-hard, it can be approximated and efficiently solved in practice. In this talk, we will review some variants of the knapsack problem that have received attention in the literature in the last years, and evaluate the state-of-the-art for these problems.

Michele Monaci is a professor of operations research at the University of Bologna, where he got a PhD degree in system engineering in 2002. From 2005 to 2016 he was assistant professor at the University of Padova. His research activity concerns the design and analysis of models and algorithms for packing and loading problems, crew scheduling and railways applications.

José Fernando Oliveira

Title: Publishing Research in OR: the other side of the mirror

Abstract: Publishing research results is fundamental to the development of any scientific field. When publishing, researchers aim to validate their scientific finds, that should be checked for relevance, correctness, originality, etc., and strive to disseminate them, namely for future research purposes. However, very frequently, bright young researchers fail to have their papers published because they do not understand how the submission and review processes work. This lack of understanding undermines their efforts and may compromise their careers. In this talk, based on the personal experience of the presenter, some insights on what journals look for in what is published, on the review process and the roles of each actor, and on how to write effective papers are provided.

José Fernando Oliveira is Full Professor and Vice-Head of the Department of Industrial Engineering and Management at the Faculty of Engineering of the University of Porto. He also teaches at Porto Business School. He is a senior researcher in the Industrial Engineering and Management Center of the research institute INESC TEC. His main area of scientific activity is Operations Research and Management Science. Within Operations Research the main research area is related to the efficient use of raw materials and other resources (cutting and packing problems), while from the techniques viewpoint his research is centered in the use and development of Metaheuristic approaches and their hybridization with Mathematical Programming based methods. He has also worked on Vehicle Routing, Lotsizing and Scheduling problems in industrial contexts. Support of decision making in Higher Education institutions management, which includes workload models, sustainability, institutional benchmarking and assessment and evaluation of institutions and teaching staff, is also one of his interests.

From his many past academic and service positions, stand out the Vice-Presidency of the Pedagogical Council of FEUP and the Vice-Presidency of the European Association of Operational Research Societies. He is currently a member of the General Council of the University of Porto, President of the Portuguese Operational Research Society and co-editor-in-chief of the European Journal of Operational Research.

Franklina Toledo

Title: Discrete model for irregular cutting problems

Abstract: The irregular cutting problem consists of cutting a set of pieces in a board. A particular

feature of the problem is related to piece shape, at least one has irregular shape. We have two main constraints associated with the problem: i) the pieces must be entirely inside the board, and ii) they do not overlap each other. The most frequently objective is to minimize the waste material. These problems are common in garment, glass, leather and furniture industries. In this tutorial, we discuss a discrete model for the nesting problem and some computational results presented in the literature.

Franklina Toledo is an Associate Professor of the Department of Applied Mathematics and Statistics, University de São Paulo (USP), Brazil. Her focus is to study mathematical integer programming models and heuristic methods to deal with cutting and packing problems and cross-docking problems. I am the Editor-in-Chief of the Journal PODes – Pesquisa Operacional para o Desenvolvimento organized by Sociedade Brasileira de Pesquisa Operacional (SOBRAPO) and an Editor of the Journal Operations Research Perspectives.

Tony Wauters

Title: On the design of (meta)heuristics

Abstract: This talk will first give a general introduction to heuristics and metaheuristics. It will be shown how to effectively design heuristic methods and some common pitfalls will be discussed. Afterwards, an overview of (meta)heuristics applied to cutting and packing will be provided, and some selected cases will be highlighted.

Tony Wauters obtained his Master degree in Engineering (2008), option Information and Communication Technology at KaHo Sint-Lieven, Gent, Belgium. In 2012 Tony obtained a PhD in Engineering (Computer Science) at the KU Leuven, titled "Reinforcement learning enhanced heuristic search for combinatorial optimization". At this moment he is working as an assistant professor at the Combinatorial Optimisation and Decision Support (CODeS) Research Group, KU Leuven, Technology campus Gent, Belgium, where he is supervising several projects and PhD students. His research focuses on the development of novel search methods for several Operations Research problems such as cutting and packing problems and scheduling problems.

Abstracts

1

A binary programming model for the quasi-polyomino tiling problem

Marcos Okamura Rodrigues* and Franklina Maria Bragion de Toledo*
* *Instituto de Ciências Matemáticas e de Computação - Universidade de São Paulo*

In this paper, we study the quasi-polyomino tiling problem. The problem consists of checking if a set of items described by quasi-polyominoes can cover a board described by a quasi-polyomino. We developed a binary programming model for the problem and conducted computational experiments to evaluate it using instances from the literature. The model outperfomed the state-of-the-art model for most instances and obtained a solution for instances with up to 47 distinct items using rotations and flips.
Keywords: Cutting and packing, Tiling, Quasi-polyomino, Binary Programming

2

An Adaptive Large Neighbourhood Search for Optimising the LEGO Construction Problem

Torkil Kollsker*, Thomas Stidsen*, Mathias Stolpe*
* *Technical University of Denmark*

The LEGO Construction Problem is the problem of deciding which bricks to place where in a predefined 3D construction. The input consists of coloured voxels that each correspond to the size of a LEGO unit, such that all LEGO bricks are multiples of this LEGO unit. While we must place bricks of a predefined colour on all visible voxels of the construction, the non-visible bricks on the inside have no colour constraints and can even be hollowed out if the construction remains stable. We limit the set of available bricks to rectangular bricks. A solution to the LEGO Construction Problem is feasible if all bricks are placed within the design domain, the bricks do not overlap, all colour constraints are obeyed, and all bricks connect into a single connected component. The objective is to minimise the number of bricks used while maximising the strength of the construction. Finding stable constructions require advanced search methods, because relatively small constructions lead to a colossal amount of possible brick combinations.

We propose to formulate this problem as a three-dimensional set-packing problem with additional connectivity constraints. We simplify the set of available bricks to have the same height. This simplification naturally decomposes the problem into multiple two-dimensional set-packing problems with linking constraints between the layers. We optimise the problem with an Adaptive Large Neighbourhood Search (ALNS). This metaheuristic starts from an initial solution and then continuously destroys a part of the construction in order to repair it in the hope of finding a better solution. We present multiple destroy and repair methods that are diverse. Our approach is adaptive, because the search adaptively chooses the destroy and repair methods that are most successful for the given problem.

In this presentation, we describe the advantages of using the ALNS and how to make the destroy and repair methods as diverse and efficient as possible. We show how to provide fast and accurate approximations to the structural stability. We conclude the presentation by looking at future improvements to our approach.
Keywords: packing, Adaptive Large Neighbourhood Search, LEGO Construction Problem, brick bonding

3

Cuts for Bin-Packing Problem using Benders Decomposition Algorithm

Eleazar Gerardo Madriz Lozada*, Yuri Tavares dos Passos*, Lucas Carvalho Souza*
* *Universidade Federal do Recôncavo da Bahia (UFRB)*

Given a set of positive sized items and an unlimited number of bins with the same capacity, the Bin Packing Problem (BPP) consists in packing all these items into the minimum number of bins. In computational complexity theory, BPP is a combinatorial NP-hard problem and the decision problem to answer if items will fit into a specified number of bins is NP-complete.

In order to overcome computational complexity, we propose cuts using Benders decomposition. Therefore, we consider an integer linear programming formulation of BPP only using binaries variables. Let n be the number of items. Then, we convert this formulation into a Linear Binary Programming Problem (LBPP) with $n^2 + n$ binary variables corresponding to placing an item in a bin plus bin usage. In LBPP formulation, we use two matrices as

restrictions. One of these matrices is a horizontal concatenation of two matrices: (i) an $n+1 \times n^2$ matrix mostly containing zeros as elements and the sizes of each item in some rows concatenated, and (ii) a matrix where the first line is filled with ones and below that line there is a diagonal $n \times n$ matrix containing the maximum capacity of each bin as diagonal elements. Another restriction matrix is a horizontal concatenation of n identity $n \times n$ matrices plus one zero $n \times n$ matrix, resulting in an $n \times n^2 + n$ matrix.
We relax LBPP with all variables in the interval $[0, 1]$ (LBPPR) and calculate its dual (DLBPPR).
For DLBPPR, we apply Benders decomposition algorithm to generate cuts for LBPP. We expect that these cuts reduce search space for BPP solution.
Keywords: Benders decomposition, Bin-Packing Problem, Cuts

4
Dynamic integrated multi-item order sizing and packing
Patrick Engelsberg*, Martin Grunewald† and Thomas Volling‡
* *Chair of Production and Logistics Management, FernUniversität in Hagen, Hagen, Germany,*
† *Volkswagen AG, Wolfsburg, Germany,*
‡ *Faculty of Economics and Management, Technische Universität Berlin, Berlin, Germany*

We consider a transport relation between a source and a sink where multiple items are transported in several loads on a daily basis, depending on orders from the sink directed to the source. At the beginning of the planning horizon, the operator of the sink places a set of orders for multiple items with the operator of the source including delivery due dates. The operator of the source needs to pack the items into the transport vehicle and deliver them to the sink. Due to limited storage space at the sink, only a small fraction of the total order volume can be advanced. Backlogging is not permitted. To determine a valid stowage plan for each transport vehicle, detailed loading constraints have to be met. Constraints concern weight, size, compatibility and bearing load of the load carriers. Several types of standardized load carriers are used to transport items to the sink. The problem is to jointly find a plan for the quantity delivered of multiple items in multiple periods and the corresponding loading plans for each transport vehicle so that the transport costs are minimized, subject to delivery due dates, capacity constraints of the sink's storage area and detailed loading constraints of the transport vehicle. We employ a two-step approach that relies on generation and combination of partial solutions (GCPS). In a first step, an enumeration of load carrier combinations forming walls is performed. Combinations are generated within compatible groups of load carriers, which means these load carriers have the same width and length as well as the same stacking characteristics. In a second step, walls are combined into loads to fulfill the demand over the planning horizon without backlogging, complying with all loading constraints as well as with the limits of storage capacity at the sink. The approach contributes to both the literature streams of multi-item order sizing by introducing detailed capacity constraints and to cutting and packing by integrating three-dimensional packing with dynamic modelling of demand. The approach shows considerable saving potential, in comparison to both, the benchmark from literature and static planning. Relevance for practice comes with the potential to solve realistic cases from the industry near to optimality in reasonable time and generating insights regarding the effects of planning horizon length, intermediate storage area size, truck utilization and coefficient of variation.
Keywords: packing, multi-item, dynamic order sizing, container loading, cutting stock, integrated problem.

5
An integrated cutting stock and scheduling problem
Lemos, Felipe Kesrouani*, Cherri, Adriana Cristina*, Araújo, Sílvio Alexandre* and Yanasse, Horácio†
* *UNESP – São Paulo State University,*
† *UNIFESP – São Paulo State Federal University*

Due date attendance is an inner concern of a production. Some cutting material industries have penalties for tardiness, sometimes as important as reducing waste.
In this work, we propose a mathematical model that combines the standard objective of minimizing the number of objects with a scheduling term penalizing the tardiness of the cutting operations. Processing times are dependent of the items in the cutting pattern. Resources must be assigned to accomplish production orders over a time horizon, respecting the operational constraints. A solution method is proposed using column generation, considering not only the size of items (knapsack problem), but also the patterns' processing times. Some valid inequalities are proposed in order to speed up the execution time to find a solution.
Computational results were performed for three sets of instances: (i) with the first set we assess the theoretical importance of considering the integrated problem; (ii) with the second set, a real dataset obtained from an

aeronautical industry, we assess the applicability of the proposed approach in practice and the real-world gains; (iii) with the third set, 60 instances randomly generated, we assess the impact of tightness and homogeneity of due dates on the computational effort for solving the problem.
Besides confirming the expected improvement of the integrated approach, the computational results showed expressive cost gains on the real-world instance, reducing the total tardiness cost and the number of objects needed. With the experiment with the random instances we observed that shorter due dates implied in bigger gaps, more CPU time and a bigger portion of tardiness cost in the objective function. On the other hand, the homogeneity of the due dates (given by the amplitude of them) implied in lower gaps.
Keywords: cutting stock problem; due dates; scheduling

6
Communication Title: Packing Clusters of Objects
I. Litvinchev*, J.A. Marmolejo†, A. Pankratov‡, T. Romanova‡
* *Nuevo Leon State University (UANL), San Nicolas de los Garza, Mexico,*
† *Panamerican University, Mexico-city, Mexico,*
‡ *Institute for Mechanical Engineering Problems of the National Academy of Sciences of Ukraine, Kharkiv, Ukraine*

A two dimensional packing problem has various important applications, e.g. in logistics. In many cases the objects are not independent and have to be grouped in a number of certain clusters of non-overlapping objects. This is typical, for example, for a container loading problem, where the objects in a large maritime container may form various clusters according to a type of objects (similar shapes, parts of the same machine). Similarly, clusters can be formed according to a supplier or a client (final destination) to facilitate loading/unloading the container. While the composition of the cluster (number of objects and their shapes) is typically predefined, the overall shape of the cluster is frequently not specified. Bearing in mind a cluster as a number of objects placed in a flexible sack we define the shape of a cluster as a convex hull of the objects in the cluster. Note that the objects are non-overlapping and the shape of the cluster (convex hull) depends on the layout of the objects in the cluster. We assume homogeneous clusters composed of the same shapes. The number of clusters as well as the number of objects and their shapes and sizes are given. Concerning optimized packing of clusters, different objectives can be used. For example, we may look for the "densest" layout fixing one dimension of the rectangular container and minimizing the other subject to feasibility of the clusters layout. On the contrary, we may fix both dimensions of the container and look for a "sparsest" layout maximizing a certain "distance" between the clusters. This objective is motivated by the need of more space between clusters to facilitate access for their loading/unloading and is used in this work. A packing problem for a number of clusters composed of convex objects is formulated. The clusters have to be packed into a given rectangular container subject to non-overlapping between objects within a cluster. Each cluster is represented by the convex hull of objects that form the cluster. Two clusters are said to be non-overlapping if their convex hulls do not overlap. A cluster is said to be entirely in the container if so is its convex hull. All objects in the cluster have the same shape (different sizes are allowed) and can be continuously translated and rotated. The objective of optimized packing is constructing a maximum sparse layout for clusters subject to non-overlapping and containment conditions for clusters and objects. New quasi phi-functions and phi-functions to describe analytically non-overlapping, containment and distance constraints for clusters are introduced. The layout problem is formulated as a nonlinear nonconvex continuous problem. A novel algorithm to search for locally optimal solutions is developed. Computational results are provided to demonstrate the efficiency of our approach.
Keywords: Packing, Object Clusters, Rectangular Container, Phi-function technique, Nonlinear Optimization

7
A matheuristic for the 3D Single Large Object Placement Problem with stability constraints
Everton Fernandes Silva*, Aline Leão†, Franklina Maria Bragion Toledo†, Tony Wauters*
* *KU Leuven,*
† *Universidade de São Paulo*

3D Packing Problems require a set of items to be placed inside a set of larger items, known as containers. For this work, the items considered are cuboid-shaped and referred to as boxes. The primary constraints of this problem are that boxes must not overlap with one another and must also be placed completely inside their respective containe's bounds.

Of the many subproblems originating from the 3D Packing Problem, this research addresses the 3D Single Large Object Placement Problem (SLOPP). The objective is to maximize the values of boxes placed inside a single container. The main characteristic of the SLOPP is that it considers a set of weakly heterogeneous boxes. Most approaches for this problem from the literature consist of specialized heuristic methods which consider only a subset of real-world constraints (stability, weight balance, rotation).
Therefore, our primary goal is to propose a well-performing method which is able to easily incorporate real-world constraints. To achieve this goal, a matheuristic is proposed for solving the SLOPP which considers rotation and stability in addition to the problem's primary constraints. Given that the items are cuboid-shaped, up to six rotations are allowed since a box axes must always be parallel with the container's. The inclusion of vertical stability constraints ensures that boxes are fully supported by requiring the base of each box to be fully overlapping with either the container floor or another box.
The proposed solution strategy consists of combining heuristic methods in addition to a MIP model taken from the literature which was shown in our previous study to be the best performing. Beginning with a relaxed heuristic solution which does not consider stability, this approach solves the MIP model containing all constraints. With the relative position of each box fixed from the initial solution, the MIP model is solved as a feasibility model. After an initial solution of good quality is obtained, an improvement heuristic is applied. This procedure also employs the same MIP with the same purpose.
By designing the solution process this way, both the initial and the improvement heuristics become independent from the problem's complete set of constraints. This means that, for any modification into the problem considered, for example, the addition of weight balance constraints besides the aforementioned ones, would require them only to be incorporated in the MIP. Experimental tests are executed on instances from the literature, with the obtained results compared against the current best known solutions.
Keywords: 3D packing, SLOPP, real-world constraints, matheuristic

8

One-dimensional Bin packing Problem: An experimental study of instances difficulty

Marcela Quiroz-Castellanos*
* *University of Veracruz, Artificial Intelligence Research Center, México*

In this communication, the one-dimensional Bin Packing Problem (BPP) is approached. BPP is a well-known NP-hard grouping optimization problem with an extensive number of industrial and logistic applications. For the solution of BPP, elaborate procedures that incorporate various techniques have been designed. Algorithms proposed in the literature range from simple heuristics to hybrid strategies, including branch and bound techniques, metaheuristics and special neighbourhood searches. The most exploited approaches, which have allowed obtaining the best results, consist mainly of: (1) the use of simple BPP heuristics; (2) the application of search space reduction methods; (3) the inclusion of local search techniques based on the dominance criterion; (4) the use of lower bounding strategies; and (5) the induction the fullest-bin pattern. The performance of the algorithms has been evaluated with different types of published problems that have been considered to be very hard. Instances proposed in the literature include 6195 benchmark instances with different features. While many benchmarks have been solved optimally, there are still instances which are not satisfactorily solved by the best state-of-the-art algorithms, even in the case of moderate sizes. It is important to identify which are the characteristics that distinguish these BPP instances and that could be the cause of its degree of difficulty. Furthermore, it is necessary to understand the algorithms' behaviour and to identify the strategies that allow for them to reach their performance. This work presents an experimental approach for the characterization and analysis of the BPP algorithmic optimization process. The proposed approach combines data analysis techniques to learn the relationships between the critical features of the BPP instances and the performance of algorithms. The knowledge gained about the instances features, the algorithms behaviour and the relations among the characteristics that define them, can be used to: (1) classify instances by degree of difficulty; (2) explain the performance of the algorithms for different instances; (3) predict the performance of the algorithms for new instances; and (4) develop new strategies of solution. Finally, the features of a BPP instance that have impact on difficulty in terms of algorithmic performance are described and used to generate a new benchmark with a high degree of difficulty. The performance of the best state-of-the-art algorithms on the new instances confirms the difficulty of the new benchmark.
Keywords: One-dimensional Bin Packing Problem, Instance difficulty, Experimental analysis

9

Use of a Mechanical Model to Predict Dynamic Stability Metrics in the Container Loading Problem for Inclusion in Optimization Strategies

Juan Martínez-Franco*, Daniel Cuellar-Usaquen*, Edgar Céspedes-Sabogal*, David Alvarez-Martínez*
* *University of Los Andes, School of Engineering, Colombia*

In the Container Loading Problem (CLP), dynamic stability is generally determined either with the use of dynamic simulations or with the use of linear regression analysis to estimate two metrics directly related to the configuration of cargo before and after transport. These metrics, which were proposed by Ramos et al. (2015), were found to be readily obtainable with the use of low precision dynamic simulation software (LPDS) that performed sufficiently accurate calculations when compared with dedicated, high precision simulation software.
This kind of software was used in the open source application PackageCargo introduced by Álvarez et al. (2018), where Physx was used to simulate the behavior of cargo when subjected to accelerations most commonly found on road vehicles as stated by international standards. The dynamic simulation environment included in the application estimated the modern dynamic stability metrics (M3 and M4) through a kinetic analysis of the kinetic parameters acting upon the cargo. Understanding that the calculations performed by the physics engine depend on traditional Newtonian mechanics applied to rigid bodies, it was possible to generate a predictive model based on linear and rotational motion equations and Coulomb friction to generate values for M3 for multiple packing patterns, or the percentage of fallen boxes (M3), one of the novel dynamic stability metrics. The other metric, number of boxes within the damage boundary curve, proved to be time dependent, so a mechanical model to predict it depended on a bulk, transient analysis of kinetic and potential energy for the entire cargo. This problem was addressed by limiting the number of time steps analyzed to only the moments where significant alterations occur within the cargo arrangement. The resulting algorithm predicted the results of the dynamic simulation for the relevant metrics with reasonable accuracy and was used to generate a new metric: overall cargo stability. This new metric depends on the mechanical concepts of stable and unstable equilibrium and is a performance indicator of how likely it is for the cargo to recover to a statically stable state after being subjected to outside forces such as the accelerations encountered during container transportation. This metric proved to be computationally inexpensive, so its use within an optimization scheme that generates packing patterns for the CLP was explored and a simple implementation is presented. All the work conducted in this paper was included into PackageCargo.
Keywords: Dynamic Stability, Decision Support Systems, Container Loading Problem, GRASP

10

Column Generation based Heuristic Algorithms for the Two-dimensional Two-stage Guillotine Cutting Stock Problem

Sue-Jeong Kwon* and Kyungsik Lee*
* *Seoul National University, Korea*

We consider a two-dimensional two-stage guillotine cutting stock problem(2D-2GCSP) where a set of rectangular items to be cut from rectangular stock materials of multiple size through two-stage guillotine cuts. We propose column generation based heuristic algorithms with classic integer programming formulation which had been proposed by Gilmore-Gomory. The size of its formulation is exponentially larger than that of the well-known other formulations such as arc-flow, one-cut and level-packing. However, the column generation procedure can tackle the large-scale integer programs efficiently. We present our computational test results with the benchmark instances. The results show that the feasible solutions of proposed algorithms are improved to solve the 2D-2GCSP compare to previous studies.
Keywords: Cutting stock problem, Two-dimensional two-stage guillotine cuts, Column generation, Heuristic algorithm

11

MULTI-START HEURISTIC FOR THE TWO-DIMENSIONAL GLASS CUTTING PROBLEM OF THE SAINTGOBAIN GLASS FRANCE COMPANY (ROADEF/EURO CHALLENGE 2018)

Germán Fernando Pantoja Benavides*, David Álvarez-Martínez*
* *Universidad de los Andes, Colombia*

The Saint-Gobain Glass France company, part of the Saint-Gobain group, specializes in the manufacture of glass coated with magnetron and float glass. The latter is produced through the flotation process, from which large sheets of glass called jumbos are obtained, which are usually cut into smaller rectangular pieces. These pieces

are obtained through a cutting pattern that considers restrictions associated with the operation, such as that the pieces must be cut in an order associated with the customer, using the jumbos in the order in which they are produced. Besides, given the physics of glass, only guillotine cuts can be performed, that is, cuts that go from one edge to another through a straight cut. It should be noted, the flotation process could cause some defects in the jumbos. When these defects are in a piece, it is generally rejected, since defects are associated with low quality. As a result, the piece has to be cut again, reducing the productivity of the production line. The company together with ROADEF and EURO launched in 2018 a challenge whose objective is to perform an algorithm that minimizes the waste of glass given a sequence of jumbos, with their respective defect maps, and a batch of pieces to be cut. The problem of the challenge is formally known as Staged Guillotine Cut, Two-Dimensional Bin Packing Problem, considering bines with defects, minimum and maximum limits of cut, and sequence of production of the pieces. This work presents a constructive multi-start algorithm, being improved with a local search procedure, based on the removal and filling of pieces. The cutting patterns are generated bin by bin, stage by stage, satisfying the constraints of the problem. The number of stages is limited to three, however, trimming is allowed, which implies the use of a fourth stage. The algorithm uses the first and second stages to form a sub-bin, in which a refined search is performed to try to locate the pieces with the help of the other stages. The selection of the pieces to locate is done by sorting and selecting the possible pieces, that is, those that satisfy all the restrictions of the problem; under one of two criteria: max-area or best-fit. The first criterion sorts the pieces by their area in a nonincreasing way, while the second criterion sorts the pieces in a non-decreasing way by measuring the minimum gap between the piece and the sub-bin. The pieces located at the beginning of the ordered list of pieces will be more likely to be selected.

1. Information related to the company and to the challenge is found in ROADEF, «SUBJECT OF THE ROADEF/EURO CHALLENGE 2018: CUTING OPTIMIZATION PROBLEM,» 15 May 2018. [Online]. Available: `http://www.roadef.org/challenge/2018/files/Challenge_ROADEF_EURO_SG_Description.pdf`

This algorithm participated in the Junior category of the challenge and classified to the final phase (which still does not end), ranking 13th out of 20 ranked teams (3th place in the contestant category). The challenge involved 60 teams from 25 countries, of which 21 teams qualified to the final phase.
Keywords: Bin with defects, multi-start heuristic, ROADEF/EURO 2018

12
An archaeological irregular packing problem
J.A.Bennell*, M. Cabo Nodar†, C. Lamas Fernandez*, A. Martinez-Sykora*
* *Southampton Business School, University of Southampton, UK,* † *Department of Mathematics, ITAM, Mexico*

The paper explores the use of cutting and packing methodologies in a new and innovative way to support archaeological research. Pre-hispanic cultures in Mexico used codices to register different aspects of their everyday life including their lands and crops. Each family register the number of pieces of land that they owned together with some measures of its dimension in a codex. These codices have been deciphered and we have accurate information about the length of each side of the pieces of land and the area they covered. Using the given dimensions, each terrain can be reconstructed as polygons. In addition, the dimensions and location of the settlements are known. This description equates to a two dimensional packing problem with an irregular bin and irregular pieces that can be rotated. While irregular shape packing has been an active research area for many years, the work focuses on packing a single strip for cutting material for manufacturing. However, while the problem at hand is quite different, we draw on the techniques arising from this research area in both geometry and algorithm design. In the presentation we will present the problem and some specific complexities that lead to the solution methodology needing to generate a range of different solutions. We present a genetic algorithm to solve this problem.
Keywords: irregular shape, single stock sheet, strongly heterogeneous small items, covering

13
Solution method for the two-dimensional cutting stock problem with usable leftovers
Douglas Nogueira do Nascimento*, Adriana Cristina Cherri†, José Fernando Oliveira‡
* *Departamento de Engenharia de Produção, FEB, UNESP, Bauru, SP, Brasil,* † *Departamento de Matemática, FC, UNESP, Bauru SP, Brasil,* ‡ *Departamento de Engenharia e Gestão Industrial, FEUP, Universidade do Porto, Portugal*

The Cutting-Stock Problem (CSP) is one of the most studied cutting and packing problem. This is due not only to its difficulty of resolution (CSP is an NP-hard problem) but also because its great practical applicability

in various industrial sectors in which minimizing the waste of raw materials is fundamental for the economic performance and the environmental management. Despite the vast literature on CSP, there are still important gaps regarding the consideration of practical characteristics that are fundamental for the adoption by companies of the methods proposed in the scientific literature. One of these characteristics is the possibility of using leftovers of previous cutting processes, which would not be considered waste. In this case, the cutting process must be planned in order to generate leftovers with a high probability of future use, minimizing the waste in a multiperiod perspective. This problem is called cutting stock problem with usable leftovers (CSPUL). In this work, we deal with the two-dimensional cutting stock problem with usable leftovers (2DCSPUL), in which, in addition to the inherent difficulty of solving (one-dimensional) cutting problems, there are increased difficulties arising from the geometric handling of objects and items, since it is necessary to recognize automatically when two items placed on a board overlap. Similarly, a second difficulty arises to guarantee that the items are kept wholly contained in the board. A mathematical model was proposed to represent the 2DCSPUL. This model uses the concept of "shelves", in which the object to be cut is divided into strips, whose heights are determined by the largest item in that strip. Also, different items can be combined to be considered a single item, to minimize the empty spaces between the strips. Regarding the leftovers, we consider they have given sizes and can be generated within a limited amount. Due to the high complexity and the large number of integer variables involved in this problem, it is computationally infeasible to solve the model using exact methods, even for small instances. Thus, heuristic procedures were developed to find integer solutions. Although heuristics do not guarantee optimality, they can provide solutions of high quality. The solution method is based on the relax-and-fix heuristic. Computational tests were run.

Keywords: Two-dimensional cutting stock problem, usable leftovers, mathematical model, heuristic procedures

14

A sim-heuristic approach for the 3D irregular packing problem

Germán Fernando Pantoja Benavides*, David Álvarez-Martínez*

* *Universidad de los Andes, Colombia*

The 3D irregular packing problems are part of the combinatorial optimization problems (COP), which have a high mathematical and computational complexity. In addition, these problems have a wide spectrum of applications in the industry where their solutions require to be of high quality and to be obtained in short computational times. The problem to tackle in this work is to minimize the volume of a cuboid in which three- dimensional concave polyhedrons of different types are packed, and free rotation of the pieces is
allowed. In the typology proposed by Wäsher et al. this problem can be classified as:

- Dimensionality: three-dimensional.
- Kind of assignment: input minimization.
- Assortment of small items: this criterion may vary from weakly heterogeneous assortment to strongly heterogeneous assortment, depending on the nature of the instances.
- Assortment of large objects: one large object.
- Shape of small items: irregular.

To solve the COP, several methodologies have been proposed that usually involve heuristics, since efficient solutions are obtained with them. Lately, combinations of various techniques have received great popularity especially the mixture of heuristics and simulation called sim-heuristics, due to the increase in computational power and the development of simulation software. In this work, a tool based on a sim-heuristic is developed using Unity®, a video game engine. Unity® incorporates colliders, a tool that can verify the overlapping between pieces and between piece-cuboid. Besides, Unity® allows programming heuristics based on movements, collisions, and forces that provide a convincing physical behavior of the elements (pieces and cuboid) due to the incorporated physics engines. The approach of this work is to perform simulations of 3D irregular packing of pieces that will be subdued under forces (movements) and collisions that will change their position. When the positions of the pieces allow the cuboid to be smaller, the faces of the cuboid will move towards the pieces to compress the volume of the cuboid. The proposed method considers three sections. First, the pieces are enclosed in a sphere using the algorithm presented in, this is done in order to facilitate their initial ubication inside the cuboid based on the biggest sphere. Second, the pieces are subdued under an increased gravity force and movements of the box that induce movement of the pieces within the cuboid. Third, the faces of the
cuboid move towards the pieces in order to decrease the volume of the cuboid. The latter are framed in a Tabu Search, in such a way that the simulation does not return to already visited states. Therefore, the transition mechanisms are the simulated accelerations and the search strategy is a simple Tabu Search algorithm. In order to compare the performance of this approach with the results available in the literature, the instances used in this

work are classical instances of concave pieces
Keywords: Irregular 3D packing, sim-heuristic, concave pieces, Unity

15
Nesting packing of circular objects
Igor Litvinchev*, J.D. Mosquera-Artamonov*, Lucero Ozunab†
* *Postgraduate in Systems Engineering. Faculty of Mechanical and Electrical Engineering. Autonomous University of Nuevo León,* † *Postgraduate in Logistics and Supply Chain. Faculty of Mechanical and Electrical Engineering. Autonomous University of Nuevo León.*

In the present work we show the results obtained by using a linear programming model to solve the problem of recursive nesting of circular objects, using a voracious heuristic with different local search strategies to improve the results obtained by the model. The best configurations obtained are schematized in their 3D representations.
Keywords: circular objects, nesting, heuristics

16
Metaheuristics to Solve Grouping Problems: A Review
Octavio Ramos-Figueroa*, Marcela Quiroz-Castellanos*
* *University of Veracruz, Artificial Intelligence Research Center, Sebastián Camacho No 5, Xalapa, Ver., México 91000 Autonomous University of Nuevo León*

Currently, a considerable amount of Grouping Problems (GPs) can be found in the specialized literature. This research area has gained great relevance because the GPs have wide applicability in problems of the industry, hospitals, universities, and airports, to mention a few examples. The solution process required by some of these problems represents a high complexity, and currently, there is no algorithm to find the optimal solution efficiently in the worst case. Such problems have been classified by the scientific community as belonging to the NP-hard class. In this study, nineteen NP-hard GPs in their simplest variants are considered, including: Bin Packing Problem (BPP), Graph Coloring (GC), Timetabling Problem (TP), Economy of Scale Problem (ESP), Parallel Machines Scheduling Problem (PMSP), among others. For these problems, the different metaheuristic approaches that have been proposed to solve them are identified and classified. The state-of-the-art suggests that: 1) to date great efforts have been carried out to facilitate the solution of GPs; 2) different solution approaches have been proposed; nevertheless, GAs have excelled in most GPs; 3) The performance of these algorithms is closely related to the heuristic strategies and the special operators used by them to explore and intensify the search, and 4) the group-based representation scheme has improved the performance of different solution algorithms in several GPs. Finally, a case study is presented, where the performance of the traditional GA and the grouping GA are compared in the PMSP with unrelated machines.
Keywords: Grouping Problems, Metaheuristics, Representation Schemes

List of Participants

Alonso Pecina , Federico
Universidad Autónoma del Estado de Morelos
Mexico
federicoalonsopecina@hotmail.com

Alvarez , David
Universidad de Los Andes
Colombia
d.alvarezm@uniandes.edu.co

Alvarez-Valdes , Ramon
University of Valencia
Spain
ramon.alvarez@uv.es

Bennell , Julia
Unversity of Leeds
UK
J.Bennell@leeds.ac.uk

Cabo , Marta
ITAM
Mexico
marta.cabo@itam.mx

Camilo Martinez , Juan
Universidad de Los Andes
Colombia
jc.martinez10@uniandes.edu.co

Carrillo del Campo , Alfredo
ITAM
Mexico
alfcar_9@hotmail.com

Chehrazad , Sahar
KU Leuven
Belgium
Sahar.Chehrazad@cs.kuleuven.be

Cherri Nicola , Adriana Cristina
Universidad Estadual Paulista
Brasil
adriana.cherri@unesp.br

Clautiaux , François
Institute de Mathematiques, Bordeaux
France
francois.clautiaux@math.u-bordeaux.fr

Cosio Leon , Maria de Angeles
Universidad Politecnica de Pachuca
Mexico
ma.cosio.leon@upp.edu.mx

Corrales Díaz , Rogelio
Universidad Autónoma de Nuevo León
Mexico
dicoro993@gmail.com

Engelsberg , Patrick
Chair of Production and Logistics Management, FernUniversität in Hagen, Hagen, Germany;
Germany
Patrick.engelsberg@fernuni-hagen.de

Fernandes da Silva , Everton
KU Leuven
Belgium
everton.fernandesdasilva@kuleuven.be

Figueroa , Ana Paulina
ITAM
México
apaulinafg@gmail.com

Esquerra Arguelles , Aned
Universidad Autónoma de Nuevo León
Mexico
anedesquerra@gmail.com

Gerardo Madriz Lozada , Eleazar
Universidade Federal do Recôncavo da Bahia (UFRB)
Brasil
eleazar@ufrb.edu.br

Han , David
Sigma TEK Systems. LLC
USA
david.han@sigmanest.com

Kesrouani Lemos , Felipe
UNESP São Paulo State University
Brasil
felipeklemos@gmail.com

Kollske , Torkil
Technical University of Denmark
Denmark
toko@dtu.dk

Kwon , Sue-Jeong
Seoul National University, Korea
Korea
sue11@snu.ac.kr

Lindsey , James
Sigma TEK Systems. LLC
USA
james.lindsey@sigmanest.com

Lopez , Claudia
UNAM
Mexico
claudia.lopez@ciencias.unam.mx

Marmolejo , José Antonio
Universidad Panamericana
México
marmolejo.antonio@hotmail.com

Martínez Noa , Alberto
Universidad Autónoma de Nuevo León
Mexico
mnalbert1409@gmail.com

Martinez Vargas , Anabel
Universidad Politecnica de Pachuca
Mexico
anabel.martinez@upp.edu.mx

Martinez-Sykora , Antonio
University of Southampton
UK
a.martinez-sykora@soton.ac.uk

Monaci , Michele
University of Bologna
Italy
michele.monaci@unibo.it

Mosquera , Jose
"Postgraduate in Systems Engineering. Faculty of Mechanical and Electrical Engineering. Autonomous University of Nuevo León"
Mexico
jose.mosqueraar@uanl.edu.mx

Ninaquispe , Mario
Universidad Nacional Tecnológica de Lima Sur - UNTELS
Perú
edison1mens@gmail.com

Nogueira do Nascimento , Douglas
Departamento de Engenharia de Produção, FEB, UNESP, Bauru, SP, Brasil
Brasil
douglas.nogueira@unesp.br

Okamura Rodrigues , Marcos
Instituto de Ciências Matemáticas e de Computação - Universidade de São Paulo
Brazil
marokamura@gmail.com

Oliveira , Jose Fernando
University of Porto
Portugal
jfo@fe.up.pt

Pantoja Benavides , Germán Fernando
Universidad de los Andes, Colombia
Colombia
gf.pantoja10@uniandes.edu.co

Quiroz-Castellanos , Marcela
University of Veracruz, Artificial Intelligence Research Center, México
Mexico
maquiroz@uv.mx

Ramos Figueroa , Octavio
Universidad de Veracruz
Mexico
oivatco.rafo@gmail.com

Toledo , Franklina
Universidad de Sao Paulo
Brasil
fran@icmc.usp.br

Wauters , Tony
KU Leuven
Belgium
Tony.Wauters@cs.kuleuven.be

Notes