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Project-Team TASC

Theory, Algorithms and Systems for Constraints

IN COLLABORATION WITH: Laboratoire d'Informatique de Nantes Atlantique (LINA)

RESEARCH CENTER
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THEME
Architecture, Languages and Compilation

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Project-Team TASC

Keywords: Constraints, Artificial Intelligence, Inference, Operations Research, Numerical Methods, Knowledge

Creation of the Project-Team: 2011 January 01.

1. Members

Faculty Members

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Gilles Chabert [Mines de Nantes, Associate Professor]
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2. Overall Objectives

2.1. Objectives of the team

2.1.1. Origin and Current Situation

Constraint programming emerges in the eighties and develops at **the intersection of Artificial Intelligence and Operations Research**, of Computer Science and Mathematics. Multidisciplinary by nature it keeps on using knowledge from various topics such as discrete mathematics, theoretical computer science (graph theory, combinatorics, algorithmic, complexity), functional analysis and optimization, IT and software engineering. Constraint programming was identified in 1996 by the ACM as a *strategic topic for Computer Science*. The turn of the century has seen the development of optimization technology in the industry (with notably Ilog, IBM, Dash and more recently Microsoft, http://code.msdn.microsoft.com/solverfoundation, Google and Dynadec) and the corresponding scientific field, at the border of Constraint Programming, Mathematical

Programming, Local Search and Numerical Analysis. Optimisation technology is now assisting public sector, companies and people to some extent for making decisions that use resources better and match specific requirements in an increasingly complex world. Indeed, computer aided decision and optimization is becoming one of the cornerstones for providing assistance to all kinds of human activities.

Today, with the preeminence of optimization technology in most industrial sectors, we argue that quick and ad hoc solutions, often used today, cannot support the long-term development of optimization technology and its broad diffusion. We also argue that there should be a much more direct link between mathematical results and their systematic reuse in the main fields of optimization technology.

2.1.2. General Challenges

In spite of its importance, computer aided decision and optimization suffers from a number of fundamental weaknesses that prevent from taking advantage of its full potential and hinder its progress and its capacity to deal with more and more complex situations. This can be mostly blamed on the diversity of actors, which are:

- Spread out in distinct scientific communities, each with its own focus:
  - On the one hand, computer science for providing languages, modelling tools and libraries. While focusing on providing flexible and powerful programming paradigm that can be easily deployed and maintained on modern architectures, it does not address the central question of how to come up in a systematic way with efficient methods for optimization and decision problems.
  - On the other hand, applied mathematics for the theory part. The focus is to come up with powerful abstractions that allow understanding the structure of a class of problems, independently of its practical and systematic uses in modern software components.
- Spread out in distinct technological communities, each independently pushing its own solving paradigm like constraint programming, linear and integer programming, continuous optimization, constraint-based local search (e.g., COMET). To some extent, most of these techniques exploit in different ways the same mathematical results, that are manually adapted to fit the main way to proceed of a given technology.

Thus, a first challenge encountered by constraint programming is the design of computer systems implementing **in a transparent way** effective solving techniques.

- Ideally, the user must be able to **describe his problem in a high level modelling language** without being concerned with the underlying solving mechanisms used. Such systems must also be independent both from any computer programming language and from any resolution engine.
- In order to assists user, systems must also offer **digital knowledge base in problem solving** that make available state of the art models and heuristics for large set of well identified problems.
- Lastly, the user must have the ability to interpret the returned solutions, in particular within the context of **over constrained problems where it is necessary to partly relax some constraints**, and that in the most realistic possible way.

A second challenge resides in the **speed of resolution especially in the context of large-scale data**. One has to adapt techniques such as generic consistency algorithms, graph algorithms, mathematical programming, meta-heuristics and to integrate them within the framework of constraint programming. This integration generates new questions such as the design of incremental algorithms, the automatic decomposition or the automatic reformulation of problems.

Finally a third challenge deals with the use of constraint programming in the context of **complex industrial problems**, especially when both discrete and continuous aspects are present. Complexity has multiple causes such as:

- the combination of temporal and spatial aspects, of continuous and discrete aspects,
- the dynamic character of some phenomena inducing a modification of the constraints and data during time,
- the difficulty of expressing some physical constraints, e.g. load balancing and temporal stability,
- the necessary decomposition of large problems inducing significant solution performance losses.

2.2. Highlights of the Year

1. Best young researcher paper for Jean-Guillaume Fages and Tanguy Lapègue at the 19th International Conference on Principles and Practice of Constraint Programming.
2. Silver medal for the library Choco at the MiniZinc International Challenge 2013 in the *open class* category.
3. Silver medal for the library Choco at the MiniZinc International Challenge 2013 in the *parallel search* category.
4. Bronze medal for Florian Richoux at the AI competitions organized at the conferences AIIDE 2013 and CIG 2013 for developing an artificial intelligence, AIUR, to play the real time strategy game $StarCraft^{tm}$, using both machine learning and constraint-based techniques.

BEST PAPER AWARD :

[30] **Filtering AtMostNValue with difference constraints: application to the Shift Minimisation Personnel Task Scheduling Problem in 19th International Conference on Principles and Practice of Constraint Programming (CP'13)**. J.-G. FAGES, T. LAPÈGUE.

3. Research Program

3.1. Overview

Basic research is guided by the challenges raised before: to classify and enrich the models, to automate reformulation and resolution, to dissociate declarative and procedural knowledge, to come up with theories and tools that can handle problems involving both continuous and discrete variables, to develop modelling tools and to come up with solving tools that scale well. On the one hand, **classification aspects** of this research are integrated within a knowledge base about combinatorial problem solving: the global constraint catalog (see http://www.emn.fr/x-info/sdemasse/gccat/index.html). On the other hand, **solving aspects** are capitalized within the constraint solving system CHOCO. Lastly, within the framework of its activities of valorisation, teaching and of partnership research, the team uses constraint programming for solving various concrete problems. The challenge is, on one side to increase the visibility of the constraints in the others disciplines of computer science, and on the other side to contribute to a broader diffusion of the constraint programming in the industry.

3.2. Fundamental Research Topics

This part presents the research topics investigated by the project:

- Global Constraints Classification, Reformulation and Filtering,
- Convergence between Discrete and Continuous,
- Dynamic, Interactive and over Constrained Problems,
- Solvers.

These research topics are in fact not independent. The work of the team thus frequently relates transverse aspects such as explained global constraints, Benders decomposition and explanations, flexible and dynamic constraints, linear models and relaxations of constraints.

3.2.1. Constraints Classification, Reformulation and Filtering

In this context our research is focused (a) first on identifying recurring combinatorial structures that can be used for modelling a large variety of optimization problems, and (b) exploit these combinatorial structures in order to come up with efficient algorithms in the different fields of optimization technology. The key idea for achieving point (b) is that many filtering algorithms both in the context of Constraint Programming, Mathematical Programming and Local Search can be interpreted as the maintenance of invariants on specific domains (e.g., graph, geometry). The systematic classification of global constraints and of their relaxation brings a synthetic view of the field. It establishes links between the properties of the concepts used to describe constraints and the properties of the constraints themselves. Together with SICS, the team develops and maintains *a catalog of global constraints*, which describes the semantics of more than 350 constraints, and proposes a unified mathematical model for expressing them. This model is based on graphs, automata and logic formulae and allows to derive filtering methods and automatic reformulation for each constraint in a unified way (see http://www.emn.fr/x-info/sdemasse/gccat/index.html). We consider hybrid methods (i.e., methods that involve more than one optimization technology such as constraint programming, mathematical programming or local search), to draw benefit from the respective advantages of the combined approaches. More fundamentally, the study of hybrid methods makes it possible to compare and connect strategies of resolution specific to each approach for then conceiving new strategies. Beside the works on classical, complete resolution techniques, we also investigate local search techniques from a mathematical point of view. These partly random algorithms have been proven very efficient in practice, although we have little theoretical knowledge on their behaviour, which often makes them problem-specific. Our research in that area is focused on a probabilistic model of local search techniques, from which we want to derive quantified information on their behaviour, in order to use this information directly when designing the algorithms and exploit their performances better. We also consider algorithms that maintain local and global consistencies, for more specific models. Having in mind the trade off between genericity and effectiveness, the effort is put on the efficiency of the algorithms with guarantee on the produced levels of filtering. This effort results in adapting existing techniques of resolution such as graph algorithms. For this purpose we identify necessary conditions of feasibility that can be evaluated by efficient incremental algorithms. Genericity is not neglected in these approaches: on the one hand the constraints we focus on are applicable in many contexts (for example, graph partitioning constraints can be used both in logistics and in phylogeny); on the other hand, this work led to study the portability of such constraints and their independence with specific solvers. This research orientation gathers various work such as strong local consistencies, graph partitioning constraints, geometrical constraints, and optimization and soft constraints. Within the perspective to deal with complex industrial problems, we currently develop meta constraints (e.g. *geost*) handling all together the issues of large-scale problems, dynamic constraints, combination of spatial and temporal dimensions, expression of business rules described with first order logic.

3.2.2. Convergence between Discrete and Continuous

Many industrial problems mix continuous and discrete aspects that respectively correspond to physical (e.g., the position, the speed of an object) and logical (e.g., the identifier, the nature of an object) elements. Typical examples of problems are for instance:

- *Geometrical placement problems* where one has to place in space a set of objects subject to various geometrical constraints (i.e., non-overlapping, distance). In this context, even if the positions of the objects are continuous, the structure of optimal configurations has a discrete nature.
- *Trajectory and mission planning problems* where one has to plan and synchronize the moves of several teams in order to achieve some common goal (i.e., fire fighting, coordination of search in the context of rescue missions, surveillance missions of restricted or large areas).
- *Localization problems in mobile robotic* where a robot has to plan alone (only with its own sensors) its trajectory. This kind of problematic occurs in situations where the GPS cannot be used (e.g., under water or Mars exploration) or when it is not precise enough (e.g., indoor surveillance, observation of contaminated sites).

Beside numerical constraints that mix continuous and integer variables we also have global constraints that involve both type of variables. They typically correspond to graph problems (i.e., graph colouring, domination in a graph) where a graph is dynamically constructed with respect to geometrical and-or temporal constraints. In this context, the key challenge is avoiding decomposing the problem in a discrete and continuous parts as it is traditionally the case. As an illustrative example consider *the wireless network deployment problem*. On the one hand, the continuous part consists of finding out where to place a set of antenna subject to various geometrical constraints. On the other hand, by building an interference graph from the positions of the antenna, the discrete part consists of allocating frequencies to antenna in order to avoid interference. In the context of convergence between discrete and continuous variables, our goals are:

- First to identify and compare typical class of techniques that are used in the context of continuous and discrete solvers.
- To see how one can unify and/or generalize these techniques in order to handle in an integrated way continuous and discrete constraints within the same framework.

3.2.3. Dynamic, Interactive and over Constrained Problems

Some industrial applications are defined by a set of constraints which may change over time, for instance due to an interaction with the user. Many other industrial applications are over-constrained, that is, they are defined by set of constraints which are more or less important and cannot be all satisfied at the same time. Generic, dedicated and explanation-based techniques can be used to deal efficiently with such applications. Especially, these applications rely on the notion of *soft constraints* that are allowed to be (partially) violated. The generic concept that captures a wide variety of soft constraints is the violation measure, which is coupled with specific resolution techniques. Lastly, soft constraints allow to combinate the expressive power of global constraints with local search frameworks.

3.2.4. Solvers

Our theoretical work is systematically validated by concrete experimentations. We have in particular for that purpose the CHOCO constraint platform. The team develops and maintains CHOCO initially with the assistance of the laboratory e-lab of Bouygues (G. Rochart), the company Amadeus (F. Laburthe), and others researchers such as H. Cambazard (4C, INP Grenoble). Since 2008 the main developments are done by C. Prud'Homme and X. Lorca. The functionalities of CHOCO are gradually extended with the outcomes of our works: design of constraints, analysis and visualization of explanations, etc. The open source CHOCO library is downloaded on average 450 times each month since 2006. CHOCO is developed in line with the research direction of the team, in an open-minded scientific spirit. Contrarily to other solvers where the efficiency often relies on problem-specific algorithms, CHOCO aims at providing the users both with reusable techniques (based on an up-to-date implementation of the global constraint catalogue) and with a variety of tools to ease the use of these techniques (clear separation between model and resolution, event-based solver, management of the over-constrained problems, explanations, etc.). Since 2009 year, due to the hiring of G. Chabert, the team is also involved in the development of the continuous constraint solver IBEX. These developments led us to new research topics, suitable for the implementation of discrete and continuous constraint solving systems: portability of the constraints, management of explanations, incrementality and recalculation. They partially use aspect programming (in collaboration with the Inria ASCOLA team). This work around the design and the development of solvers thus forms the fourth direction of basic research of the project.

4. Application Domains

4.1. Introduction

Constraint programming deals with the resolution of decision problems by means of rational, logical and computational techniques. Above all, constraint programming is founded on a clear distinction between, on the one hand the description of the constraints intervening in a problem, and on the other hand the techniques used for the resolution. The ability of constraint programming to handle in a flexible way heterogeneous constraints has raised the commercial interest for this paradigm in the early nighties. Among his fields of predilection, one finds traditional applications such as computer aided decision-making, scheduling, planning, placement, logistics or finance, as well as applications such as electronic circuits design (simulation, checking and test), DNA sequencing and phylogeny in biology, configuration of manufacturing products or web sites, formal verification of code.

4.2. Panorama

In 2012 the TASC team was involved in the following application domains:

- *Planning and replanning* in Data Centres SelfXL project).
- *Packing complex shapes* in the context of a warehouse (NetWMS2 project).
- Building decision support system for *city development planning with evaluation of energy impacts* (SUSTAINS project).
- *Optimizing electricity production* in the context of the Gaspard Monge call program for Optimisation and Operation Research. We extract global constraints from daily energy production temporal series issued from all productions plants of EDF over a period of several years.

5. Software and Platforms

5.1. CHOCO

Participants: Nicolas Beldiceanu, Alexis de Clerq, Jean-Guillaume Fages [main developer], Narendra Jussien [correspondant], Arnaud Letort, Xavier Lorca [correspondant], Thierry Petit, Charles Prud'Homme [main developer], Remi Douence.

CHOCO is a Java discrete constraints library integrating within a same system *explanations*, *soft constraints* and *global constraints* (90000 lines of source code). This year developments were focussing on the following aspects:

1. Since September 2011, we are working on a new version of the CHOCO solver. This implies a total refactoring of the source code in order to make it simpler to use and maintain. We introduce a new propagation engine framework that directly handle state-of-the-art techniques, such as *advisors*, *propagator groups*, *activity-based search* and *explanations*, to ensure a good level of efficiency, and plug a MiniZinc modeling language parser. An alpha release will be available by the beginning of 2013.
2. In the context of the new version of the CHOCO solver we design an *adaptive propagation engine* to enhance performance as well as a *solver independent language to write strategies* for controlling the new adaptive propagation engine. The adaptive propagation engine can both deal with variable-oriented propagation engines and constraint-oriented propagation engines. It is usually accepted that there is no best approach in general and modern constraint solvers therefore implement only one.
3. New scalable global constraints were provides both in the context of *graph constraints* (with also graph variables) and in the context of *scheduling constraints*. These constraints respectively allow to handle sparse graphs with up to 10000 vertices, and resource scheduling problems with up to one million tasks.
4. A new global constraint called *focus* for concentrating high cost values motivated by several concrete examples, such as resource constrained scheduling problems with machine rentals, was introduced.
5. The work on providing probability-based constraints to get light propagation filtering algorithm has been pursued. A particular focus has been put on calculating the probabilistic indicator for the bound-consistency propagator of an *alldifferent* constraint.
6. A stable version of Choco, tagged 3.1.0, is available since September 2nd 2013. This version won two silver medals in the MiniZinc Challenge 2013. It has been downloaded more than 4000 times between September and December 2013.

The link to the system and documentation is http://choco.emn.fr.

5.2. IBEX

Participants: Ignacio Salas Donoso, Anthony Baire, Gilles Chabert [correspondant], Rémi Douence, Bertrand Neveu, Gilles Trombettoni.

IBEX (Interval-Based EXplorer) is a C++ library for solving nonlinear constraints over real numbers (25000 lines of source code). The main feature of Ibex is its ability to build solver/paver strategies declaratively through the contractor programming paradigm.

In 2013 the work on IBEX has focussed on the following points.

- Continuing last year work on the redesign of the architecture, the IBEX library has been augmented with new features. First, *affine forms* (with the help of Jordan Ninin) have been introduced in core calculations as an alternative to interval arithmetic. Five different implementations are under testing. A symbolic differentiation module has been developed and used for applying first-order conditions in global optimization (an interval variant of Khun-Tucker conditions). We have started a redesign of the global optimizer to integrate properly first-order conditions and exact equality constraints (not relaxed to inequalities). This work will be pursued in early 2014.
- In deterministic continuous constrained global optimization, upper bounding the objective function generally resorts to local minimization at several nodes of the branch and bound. We have proposed an alternative approach when the constraints are inequalities and the feasible space has a non-null volume. First, we extract an inner region, i.e., an entirely feasible convex polyhedron or box in which all points satisfy the constraints. Second, we select a point inside the extracted inner region and update the upper bound with its cost. We have implemented this principle with two inner region extraction algorithms, once being based on the algorithm published in CP'10 by G. Chabert & N. Beldiceanu for sweeping with continuous domains. The corresponding paper is *Upper Bounding in Inner Regions for Global Optimization under Inequality Constraints* that has been accepted for publication in JOGO (Journal of Global Optimization).
- The packaging of IBEX has also been considerably enhanced with the integration of a 3rd interval library (Filib++) and a 2nd LP solver (CPlex) and by making the library compatible with 64-bits platforms. The writing of documentation and tutorials has continued. A document of specifications has also been written for an automatic benchmarking tool.

5.3. CHOCO-IBEX

Participants: Gilles Chabert [correspondant], Jean-Guillaume Fages [correspondant], Charles Prud'Homme [correspondant].

Work has been done to provide an interface for connecting the CHOCO and the IBEX libraries in order to handle problems where we both have continuous and discrete variables. This interface allows to filter continuous domains from CHOCO with the IBEX engine as well as to check for unsatisfiability or entailment. It also manages reification variables. The "Choco-Ibex" interface, initially designed for filtering only, has been augmented with *inflators*, a generic service on which the hybrid *geost* sweep algorithm is based. This gives a basis for a possible implementation of a future hybrid packing solver (objects with curved shapes), the target application of the NetWMS2 project. The interface is available in Choco-3.1.0.

5.4. Artificial Intelligence Using Randomness

Participant: Florian Richoux [correspondant].

AIUR (Artificial Intelligence Using Randomness) is an AI for $StarCraft:\ BroodWar^{tm}$.

The main idea is to be unpredictable by making some stochastic choices. The AI starts a game with a "mood" randomly picked up among 5 moods, dictating some behaviors (aggressive, fast expand, macro-game, ...). In addition, some other choices (productions, timing attacks, early aggressions, ...) are also taken under random conditions.

Learning is an essential part of AIUR. For this, it uses persistent I/O files system to record which moods are efficient against a given opponent, in order to modify the probability distribution for the mood selection.

AIUR is an open source program under GNU GPL V3 licence, written in C++ (18.000 lines of code). Source and documentations are available at http://code.google.com/p/aiurproject/. AIUR finished 3rd to $StarCraft^{tm}$ AI competitions organized at the conferences AIIDE 2013 and CIG 2013.

5.5. Global Constraint Catalog

Participants: Nicolas Beldiceanu [correspondant], Mats Carlsson, Helmut Simonis.

The global constraint catalog presents and classifies global constraints and describes different aspects with meta data. It consist of

1. a pdf version that can be downloaded from http://www.emn.fr/z-info/sdemasse/gccat/ (at item *last working version*) containing 423 constraints, 3936 pages and 900 figures,
2. an on line version accessible from the previous address,
3. meta data describing the constraints (buton *PL* for each constraint, e.g., alldifferent.pl),
4. an online service (i.e, a *constraint seeker*) which provides a web interface to search for global constraints, given positive and negative ground examples.

This year developments were focussing on:

1. maintaining the catalogue,
2. making the *core global constraints* (10 constraints) more accessible to a wider audience:
   - for this purpose examples with their corresponding pictures have been systematically provided for showing all solutions for an example of each core global constraint.
   - in addition a set of about 55 exercises with their corrections have been done for half of the core global constraints.
3. a redesign of all the 900 figures of the catalog has been undertaken in autumn 2012 using TikZ (in December 2013 750 figures were redesigned).
4. adding counting information related to the number of solutions of a constraint (integer sequences and visualization).
5. adding constraints related to sequences that we found relevant for learning constraints from electricity production curves.

6. New Results

6.1. Solvers

Participants: Nicolas Beldiceanu, Rémi Douence, Narendra Jussien, Xavier Lorca, Eric Monfroy, Charles Prud'Homme.

- [14] presents some research directions wrt sustainable solver development based on the idea that solvers should be based/derived on data bases of combinatorial knowledge.
- [19] and [42] presents a solver independent language dealing both with variable-oriented and constraint-oriented propagation engines to enable the design of propagation engines.
- By observing the resolution process, [35] shows how to dynamically adapt the resolution while propagating constraints.

6.2. Filtering

Participants: Nicolas Beldiceanu, Alban Derrien, Jérémie Du Boisberranger, Jean-Guillaume Fages, Arnaud Letort, Xavier Lorca, Thierry Petit, Charlotte Truchet, Mohamed Wahbi.

- Given a matrix model, with the same constraint defined by a finite-state automaton on each row and a global cardinality constraint on each column, [12] exploits double counting to derive necessary conditions on the cardinality variables of the global cardinality constraints from the automata. (participants: Beldiceanu)
- By using the observation that most global constraints can be reformulated as a conjunction of a total function constraint together with a constraint that can be easily reified (e.g. a linear constraint involving two variables), [13] introduces a simple way for deriving reified global constraints. (participants: Beldiceanu)
- In the context of distributed constraint solving [22], [25] introduce two filtering algorithms that extend Asynchronous Forward Checking (AFC). The last one outperforms AFC specially on sparse problems. (participants: Wahbi)
- We improve the energetic reasoning checker of the cumulative constraint by decreasing the number checked intervals by a factor seven. We prove this approach can be generalized to the ER filtering algorithm. Furthermore, in a context of makespan minimization of hard problems, our experiments demonstrate that associating this checker with a Time-Table propagator is more efficient than using the best state-of-the-art propagators, such as Time-Table Edge-Finding. This work is at the core of Alban Derrien's doctoral research (Alban is a PhD student of TASC). It was published at the doctoral program of CP2013 [28]. (participants: Derrien, Petit)
- [29] introduces a probabilistic model for the bound consistency algorithm of the alldifferent constraint in order to decrease the number of times the constraint is woken without making new deductions during constraint propagation. (participants: Du Boisberranger, Lorca, Truchet).
- Initially motivated by the shift minimisation personal task scheduling problem [30] shows how to integrate difference constraints into the AtMostNValue constraint in order to get a better estimation about the minimum number of distinct values. (participants: Fages, Lorca)
- Motivated by scalability issues, and based on the idea of accelerating the convergence to the fix-point by filtering several cumulative constraints in parallel, [33] and [47] presents a sweep based algorithm for a conjunction of cumulative constraints. (participants: Beldiceanu, Letort)
- [46] come up with a more efficient filtering algorithm than the one introduced for the cost regular constraint for dealing with constraints for which the set of solutions can be represented by an automaton with counters. (participants: Beldiceanu)

6.3. Continuous/discrete

Participants: Nicolas Beldiceanu, Gilles Chabert, Jean-Guillaume Fages, Charles Prud'Homme.

- While convexity (and some of its generalisations) is a key property used for dealing with continuous constraints it was not yet used in the context of discrete global constraints. In [34] we come up with a parametric filtering algorithm based on a form of convexity. It can handle in a uniform way various constraints such as deviation, spread or the conjunction of a linear inequality constraint and count constraint.
- Motivated by hybrid discrete continuous problems we come up in [44] with a simple and efficient interface for connecting a discrete constraint solver (Choco) and a continuous constraint solver (Ibex).

6.4. Learning Constraint Models

Participants: Nicolas Beldiceanu, Naina Razakarison.

- In the context of learning parametrized constraint models for highly structured problems we address in [38] the problem of finding the coefficients of polynomials in several variables from example parameter and function values.
- In the context of semi structured time series where the structural aspect is related to technological constraints we deal in [24] with the problem of extracting functional dependency constraints. The problem is motivated by extracting constraints from electricity production time series and is characterized by a larger set of samples (from 7 years and from 300 plants).

6.5. Meta Heuristics

Participants: Alejandro Reyes Amaro, Eric Monfroy, Florian Richoux, Charlotte Truchet.

- The aim is to develop and implement new algorithmical methods for constraint problems on massively parallel machines. We also conduct more theoretical studies about the parallelization of constraint problems. This year, we proposed a fairly sharp model to predict parallel speed-ups one can expect while parallelizing by a multi-walk parallel scheme any Las Vegas algorithm by just studying the distribution of sequential run-times [41]. This model shows a divergence of only 20% when predicting speed-ups over 256 cores, on very different benchmarks.
- To evaluate the scalability and parallelization of local search algorithms for SAT, [23] presents a statistical method based on the analysis of the runtime behavior of its sequential version.
- [26] and [26] deals with the use of metaheuristics for solving the resource constrained scheduling problem and the set covering problems.

6.6. Search and modelling

Participants: Eric Monfroy, Thierry Petit.

- In the context of autonomous search, [21] deals with the problem of automatically tuning a search strategy (i.e., variable value selection). For this purpose it uses so called *choice functions* which provide an evaluation of a strategy in term of a set of indicators. [36] and [31] go one step further by providing tuning and adaptation facilities at the level of the different components of a constraint solver.
- Using the MiniZinc modeling language, [32] shows how to model and solve the portfolio selection problem with constraint programming. Since more than ten year constraints for which the set of solutions can be matched to the language accepted by an automaton were introduced in many solvers (e.g., Choco, Gecode, SICStus). [40] describes an interface for describing such constraints in a more convenient way.
- Many discrete optimization problems have constraints on the objective function. Being able to represent such constraints is fundamental to deal with many real world industrial problems. In this work, we go one step further in the concept of topologically concentrate high values in a sequence of cost variables. We refine the work we previously published in CP2012 thanks to three generalizations of the focus constraint. We experiment successfully the technique in scheduling, round-robin and musical benchmarks. This work has been published at IJCAI 2013 [37].

6.7. Miscellaneous

Participants: Eric Monfroy, Florian Richoux.

- [15] gives a complete characterization of the complexity of the existential positive first-order logic, that one can interpret as model checking on monotone csp. We exhibit a dichotomy criterion remaining the same on finite domains of every cardinality, as well as countable and uncountable infinite domains.
- We develop an artificial intelligence, AIUR, to play the real time strategy game $StarCraft^{tm}$, using both machine learning and constraint-based techniques. AIUR finished 3rd to $StarCraft^{tm}$ AI competitions organized at the conferences AIIDE 2013 and CIG 2013. [18] presents a survey on AI techniques applied on $StarCraft^{tm}$.

7. Bilateral Contracts and Grants with Industry

7.1. Ligéro(AGIRA)

Participants: Xavier Lorca, Thierry Petit.

Title: Ligéro.

Duration: 2013.

Type: Regional research group

Teaching optimization project.

7.2. CPER

Participant: Charles Prud'Homme.

Title: CPER.

Duration: 2010-2014.

Type: Regional research group.

Budget: 250000 Euros.

Others partners: EMN (team ATLANMOD), EMN (team ASCOLA), IRCCyN (team SLP).

Develop, promote and build up an eco-system around free software in the Pays de la Loire region. The TASC team is involved in the maintenance and development of the free constraint programming platform CHOCO.

7.3. UNIT

Participants: Nicolas Beldiceanu, Eliane Vacheret.

Title: UNIT.

Duration: 2011-2013.

Type: Developing teaching material.

Budget: 5000 Euros.

Others partners: EMN (CAPE).

Pedagogical material and software for learning constraints programming for non experts (integrated within the global constraint catalog). The course will be available on line in spring 2014.

7.4. FUI SUSTAINS

Participants: Charlotte Truchet, Bruno Belin.

Title: SUSTAINS.

Duration: 2010-2015.

Type: FUI.

Budget: 151400 Euros.

Others partners: Artefacto, Artelys, Areva TA, EPAMarne, LIMSI.

The SUSTAINS project (*Constraint-based Prototyping of Urban Environments*) aims at building decision support system for city development planning with evaluation of energy impacts. The project is focussed on spatial allocation of typical units such as industrial areas, commercial areas and leaving areas with their respective appropriate infrastructure. Its integrates sustainability, transport and energy concerns.

7.5. ANR BOOLE

Participants: Vincent Armant, Jérémie Du Boisberranger, Xavier Lorca, Charlotte Truchet.

Title: BOOLE.

Duration: 2010-2013.

Type: open research program.

Budget: founding a PhD student and travels.

Others partners: Univ. de Versailles Saint-Quentin, Univ. Caen, Univ. Paris 8, Univ. Aix-Marseille, Univ. Paris Nord, Univ. Paris 11, ENS Paris.

Défi: Probabilistic method for combinatorial problems.

The work of TASC focuses on the use of probabilistic methods to avoid waking systematically global constraints for nothing. The goal is to provide probabilistic models for the consistency of global constraints such as *alldifferent* or *nvalue*. We compute the probability of a constraint to be still consistent after fixing one of its variables and provide an approximation that can be computed in constant time. The PhD of J. du Boisberranger is co-supervised with D. Gardy from Univ. de Versailles Saint-Quentin.

7.6. ANR NetWMS2

Participants: Nicolas Beldiceanu, Gilles Chabert.

Title: Networked Warehouse Management Systems 2: packing with complex shapes.

Duration: 2011-2014.

Type: cosinus research program.

Budget: 189909 Euros.

Others partners: KLS Optim and CONTRAINTES (Inria Rocquencourt).

This project builds on the former European FP6 Net-WMS Strep project that has shown that constraint-based optimisation techniques can considerably improve industrial practice for box packing problems, while identifying hard instances that cannot be solved optimally, especially in industrial 3D packing problems with rotations, the needs for dealing with more complex shapes (e.g. wheels, silencers) involving continuous values. This project aims at generalizing the geometric kernel *geost* for handling non-overlapping constraints for complex two and three dimensional curved shapes as well as domain specific heuristics. This will be done within the continuous solver IBEX, where discrete variables will be added for handling polymorphism (i.e., the fact that an object can take one shape out of a finite set of given shapes). In 2013 a filtering algorithm has been devised in the case of objects described by nonlinear inequalities and is now under testing with the Ibex library. This work has been presented in a workshop on interval methods & geometry in ENSTA Bretagne.

7.7. ANR INFRA-JVM

Participants: Xavier Lorca, Charles Prud'Homme.

Title: Towards a Java Virtual Machine for pervasive computing.

Duration: 2011-2013.

Type: **new project**.

Budget: 78000 Euros.

Others partners: Univ. Paris 6 (REGAL team), LaBRI (LSR team), IRISA (TRISKELL).

The INFRA-JVM project will investigate how to enhance the design of Java virtual machines with new functionalities to better manage resources, namely resource reservation, scheduling policies, and resource optimization at the middleware level. TASC is concerned with this later aspect. The performance of CHOCO will be improved using the memory snapshot mechanism that will be developed.

7.8. EDF

Participants: Nicolas Beldiceanu, Helmut Simonis.

Within the context of the Gaspard Monge call program for Optimisation and Operation Research we work with EDF on the research initiative on *Optimization and Energy*. The goal of the project (continuation of last year project) is first to extract constraints from daily energy production temporal series issued from the 350 production plants of EDF, second to see how to use these constraints in order to reduce the combinatorial aspect of the daily production planning solving process. The work is based on the CP 2012 model seeker.

7.9. LabCom

Participants: Charles Prud'Homme, Xavier Lorca.

Title: TransOp.

Duration: 2014-2016.

Type: **new project**.

Budget: 300000 Euros.

Others partners: Eurodécision.

The goal of the project is to handle robustness in the context of industrial timetabling problems with constraint programming using CHOCO.

7.10. PHC Ulysses

Participants: Charlotte Truchet, Florian Richoux, Alejandro Reyes.

Title: Development and estimation analysis of massively parallel local search approaches to the k-medoids problem.

Duration: 2014.

Type: **new project**.

Budget: 2500 Euros.

Others partners: 4C (Cork, Ireland).

The goal of this project is to develop parallel local search techniques for solving large instances of the k-medoids problem, a location problem with several applications, in particular in optical fiber networks deployment.

7.11. ECOS Sud

Participant: Eric Monfroy.

Title: Auto-Evol (Autonomous Evolutionary Algorithms).

Duration: 2011-2013.

Budget: 15 KEuros per year for the project.

Others partners: LERIA (Angers, France), Univ. Austral de Chile (Chili), UTFSM (Valparaiso, Chili).

8. Partnerships and Cooperations

8.1. Regional Initiatives

- AGIRA project (LigéRO) *Teaching optimization project*.

8.2. National Initiatives

- Development of IBEX with Jordan Ninin and Luc Jaulin from ENSTA Bretagne, Bertrand Neveu from ENPC PariTech, and Gilles Trombettoni from Lirmm.
- Work on a conference and journal paper on optimization problems with Mohamed Siala, PhD student at LAAS, Toulouse.
- Collaboration with F. Pachet and P. Roy, Sony music, Paris.

8.3. International Initiatives

8.3.1. Inria Associate Teams

Inria Associated Team Bananas

- Partners: Inria-Lorraine, PUCV (Chili), UTFSM (Chili), Univ. Angers (LERIA), Univ. Nantes (TASC).
- Duration: 2012-2014.
- Topics: Autonomous constraint solving, SMT solvers.
- Budget: 15 KEuros per year for the project.

8.3.2. Inria International Partners

8.3.2.1. Informal International Partners

- SICS, Sweden: Work on the *global constraint catalog* and on *scalable constraints* with Mats Carlsson.
- Uppsala University, Sweden: Work on automata and dedicated filtering algorithms for some constraint patterns with the ASTRA group of Pierre Flener.
- JFLI, Japan: Work with Philippe Codognet.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

Helmut Simonis (4C): work on model learning and work on learning constraints in the context of EDF, three months.

8.4.2. Visits to International Teams

- N. Beldiceanu, 4C Cork Ireland: work on *learning generic models* and work on *learning constraints in the context of EDF* with H. Simonis.
- N. Beldiceanu, Uppsala University and SICS: work on *automata and constraints* with P. Flener and J. Pearson and on *learning generic models* with M. Carlsson.
- Eric Monfroy, Univ. Austral de Chile, Valparaiso, Chile: work on autonomous search with B. Crawford and R. Soto.

9. Dissemination

9.1. Scientific Animation

- Nicolas Beldiceanu:
  - Head of the Inria TASC team and LINA TASC team.
  - Member of the program committee of CP 2013.
  - Member of the program committee of CPAIOR 2013.
  - Member of the program committee of CPAIOR 2014.
  - Member of the program committee of CP 2014.
  - Reviewer for the Constraints Journal.
- Fréderic Benhamou:
  - Vice-President for Research of Nantes University, France.
- Gilles Chabert:
  - Member of the program committee of JFPC 2013.
  - Reviewer for CP 2013.
  - Reviewer for IJCAI 2013.
  - Supervision PhD committee Aymeric Bethencourt (ENSTA Bretagne), Gilles Chabert.
  - Supervision PhD committee of Remy Guyonneau (ISTIA Angers), Gilles Chabert.
- Sophie Demassey:
  - Member of the application track program committee of CP 2013.
- Jean-Guillaume Fages:
  - Member of the program committee of JFPC 2014.
- Narendra Jussien:
  - Head of the computer science department at EMN.
  - Director of the series *Operations Research and Constraint Programming* from ISTE/Wiley.
  - Member of the program committee of CP 2013.
  - Member of the program committee of CPAIOR 2013.
- Xavier Lorca:
  - Member of the program committee of JFPC 2013.
  - Managing the topic *constraints and optimization* within the LINA.
  - Member of the LINA lab council.
  - Reviewer for IJCAI 2013.
  - Reviewer for RAIRO.

  - Reviewer for the Constraints Journal.
- Eric Monfroy:
  - Co-chair of the ACM SAC CSP track 2013.
  - Co-chair of the ACM SAC CSP track 2014.
  - Member of the program committee of CHR 2013.
  - Member of the program committee of JFPC 2013.
  - Reviewer for IEEE TEC.
  - Reviewer for Information Sciences (Elsevier).
  - Co-Editor of the CP Newsletter (until july 2013).
  - Member of the *Conseil d'Administration* of the AFPC.
- Charles Prud'Homme:
  - Member of the program committee of JFPC 2014.
- Florian Richoux:
  - Member of the program committee of Learning and Intelligent OptimizationN Conference" 2014 (LION 8).
  - Member of the program committee of ACM Symposium On Applied Computing 2014 (SAC'14).
  - Member of the program committee of JFPC 2014.
  - Reviewer for the journal IEEE Transactions on Computational Intelligence and AI in games.
  - Reviewer for the conference CP 2013.
- Thierry Petit:
  - Co head of the LINA TASC team.
  - Member of the program committee of CP 2013.
  - Member of the program committee of CPAIOR 2014.
  - Member of the program committee of ECAI 2014.
  - Program chair of JFPC 2014.
  - Reviewer for the Constraints Journal.
- Charlotte Truchet:
  - Equal Opportunity Officer for Nantes University since October 2012, for gender equality issues.
  - Program chair of JFPC 2013.
  - Member of the program committee of JFPC 2014.
  - Reviewer for IJCAI 2013.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Master: N. Beldiceanu, Constraint (Master ORO), 30h, M2, Nantes University, France.

Master: N. Beldiceanu, Logic Programming, 32h, M2, Mines de Nantes, France.

Master: N. Beldiceanu, Gipad end project, 8h, M2, Mines de Nantes, France.

Licence: N. Beldiceanu, Imperative Programming, 12h, L3, Mines de Nantes, France.

Licence: N. Beldiceanu, Interface, 12h, L3, Mines de Nantes, France.

Master: G. Chabert, Non-linear programming, 20h, M2, Mines de Nantes, France.

Master: G. Chabert, Non-linear optimization, 20h, M1, Mines de Nantes, France.

Master: G. Chabert, Non-linear optimization, 24h, M1, Nantes University, France.

Licence: G. Chabert, Variational calculus, 12h, L3, Mines de Nantes, France.

Licence: G. Chabert, Numerical methods, 21h, L3, Mines de Nantes, France.

Licence: G. Chabert, Simulation and parameter estimation, 18h, L3, Mines de Nantes, France.

Licence: G. Chabert, Numerical integration, 15h, L3, Mines de Nantes, France.

Licence: G. Chabert, Supervisions of projects, 66h.

Master: X. Lorca, Head of the major of the Master in Engineering, Computer Science for Decision Support, 30h, M2, Mines de Nantes, France.

Master: X. Lorca, Algorithms and Complexity, 20h, M1, Mines de Nantes, France.

Master: X. Lorca, Data Warehouse and Data Analysis, 20h, M1, Mines de Nantes, France.

Master: X. Lorca, Graph Theory, Algorithms, 20h, M1, Mines de Nantes, France.

Master: X. Lorca, Business Intelligence, 20h, M2, Mines de Nantes, France.

Master: X. Lorca, IT System and Software Development, 20h, M2, Mines de Nantes, France.

Master: X. Lorca, Implementation Project, 20h, M2, Mines de Nantes, France.

Licence: E. Monfroy, Algorithm, 40h, L1, Nantes University, France.

Licence: E. Monfroy, Algorithm 2, 16h, L2, Nantes University, France.

Licence: E. Monfroy, Logic, 40h, L2, Nantes University, France.

Licence: E. Monfroy, Language theory, 96h, L3, Nantes University, France.

Master: T. Petit, Director of the Discrete Optimization degree, M2, GIPAD, Mines Nantes, France.

Master: T. Petit, Director of the Artificial Intelligence and Constraint Programming degree, M2, GIPAD, Mines Nantes, France.

Master: T. Petit, Scheduling and optimization, M2, 18h, Mines de Nantes, France.

Master: T. Petit, Constraint Programming in Choco, M2, 20h, Mines de Nantes, France.

Master: T. Petit, Supervisor of two final 6 months projects, M2, 12h, Mines de Nantes, France.

Licence: T. Petit, Data structures, L2, 20h, Mines de Nantes, France.

Licence: T. Petit, SQL, L2, 19h, Mines de Nantes, France.

Licence: T. Petit, HMI, L2, 13h , Mines de Nantes, France.

Licence: T. Petit, Data processing integration in HMI, L2, 10h, Mines de Nantes, France.

Licence: T. Petit, Java, L1, 40h, Mines de Nantes, France.

Licence: T. Petit, IPIPIP project, L1, 5h, Mines de Nantes, France.

Licence: T. Petit, ACDC project, L1, 7.5h, Mines de Nantes, France.

Master: F. Richoux, Constraint Programming, 12h, M2, University of Nantes, France.

Licence: F. Richoux, Design Patterns in Object-Oriented Programming, 86h, L3, University of Nantes, France.

Licence: F. Richoux, Algorithm and Data Structures, 45h, L2, University of Nantes, France.

Licence: F. Richoux, Introduction to Computer Science, 28h, L1, University of Nantes, France.

Licence: Charlotte Truchet, Algorithms and Programming, 46h, L1, University of Nantes, France.

9.2.2. Supervision

PhD: Arnaud Letort, Scalable multi-dimensional resources scheduling constraints [11], Nantes University, October 28 2013, Nicolas Beldiceanu.

Internship of Julie Laniau with Charlotte Truchet on *using constraints for checking audio real time programs* (from February 2013 to June 2013).

PhD in progress: Bruno Belin, Interactive conception of sustainable urban environments with constraints, September 2011, Charlotte Truchet, Marc Christie, Fréderic Benhamou.

PhD in progress: Jean Guillaume Fages, Graph Theory in Constraint Programming, Theory and application to several graph covering problems, October 2011, Xavier Lorca, Nicolas Beldiceanu.

PhD in progress: Charles Prud'Homme, Controlling Propagation and Search within a Constraint Solver, October 2011, Xavier Lorca, Narendra Jussien, Rémi Douence, defense planned for February 2014.

PhD in progress: Alban Derrien, Constraint propagation with limited time complexity, October 2012, Thierry Petit, Nicolas Beldiceanu.

PhD in progress: Ignacio Sala Donoso, Packing curved shapes, May 2013, Gilles Chabert, Nicolas Beldiceanu.

PhD in progress: Alejandro Reyes Amaro, New parallel algorithms for combinatorial optimization, October 2013, Florian Richoux, Eric Monfroy.

9.2.3. Juries

- N. Beldiceanu, Member of the PhD committee of the thesis of Arnaud Letort (Univ. Nantes, October 28, 2013).
- G. Chabert, Member of the PhD committee of the thesis of Remy Guyonneau (ISTIA Angers).

9.3. Popularization

- Within the context of the global constraint catalog:
  - we provide more exercises (up to 55 currently) with their solution and a web version allowing some interaction will be available in spring 2014.
  - the effort for converting and completing the 900 figures of the catalog using TikZ has been continued up to a point where beginning 2014 only 150 figures need still to be converted.
- Within the context of the library IBEX the following courses were given:
  - A workshop in June and December 2013 in Brest (ENSTA).
  - A user oriented course in July 2013 at the doctoral days of the GDR Macs in Strasbourg.
  - A developer oriented course *IBEX days* in October 2013 in Paris (Ecole des Ponts, Paritech).
- A the 2013 edition of the Fête de la Science (Nantes University):
  - Two talks on *Artificial Intelligence and real time strategy games* were given by Florian Richoux.
  - One talk on *Challenges around optimizations problems* was given by Xavier Lorca.
  - One half day discussing and answering questions around the work of professor and researcher in computer science with young persons (17 years old) was spent by Nicolas Beldiceanu.

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