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MIDACO-SOLVER

Global Optimization Software for Mixed Integer Nonlinear Programming

Abstract

MIDACO is a solver for general optimization problems. MIDACO can be applied on continuous (NLP), discrete/integer (IP) and mixed integer (MINLP) problems Problems may be restricted to equality and/or inequality constraints. MIDACO is suitable for problems with up to several hundreds to some thousands optimization variables. MIDACO implements a derivative-free, heuristic algorithm that treats the problem as black-box which may contain critical function properties such as non-convexity, discontinuities or stochastic noise. For cpu-time expensive applications, MIDACO offers an efficient parallelization strategy. The software is available in several programming languages, such as Matlab/Octave, Python, C/C++ and Fortran.

Optimization Problem

MIDACO solves **MINLP optimization problems** of the following form:

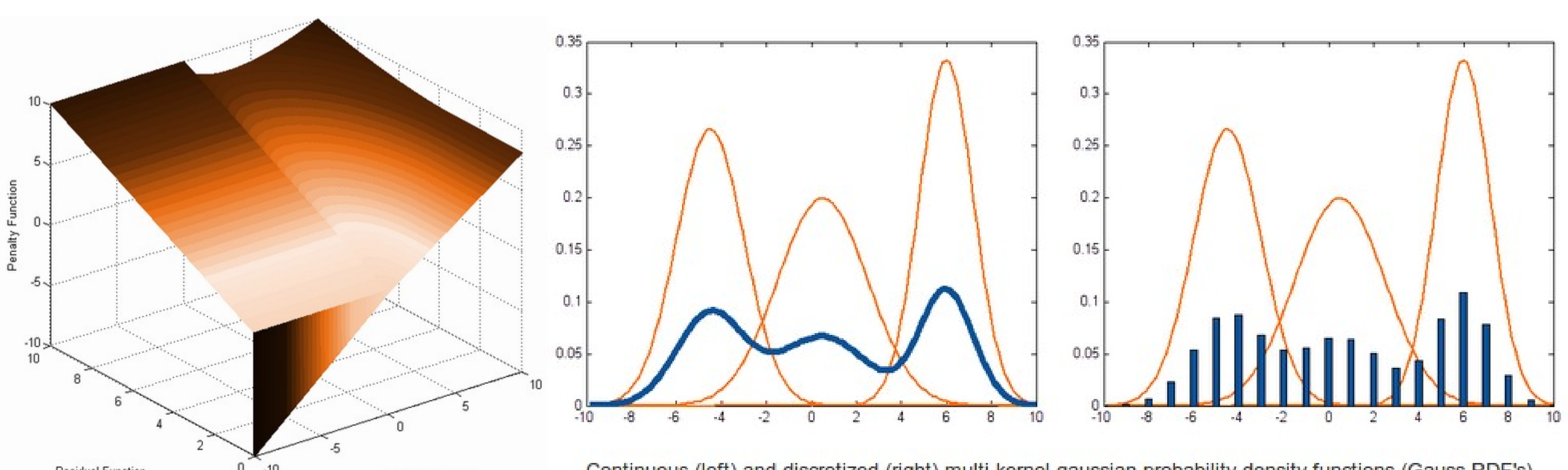
$$\text{Minimize} \quad f(x,y) \qquad (x \in \mathbb{R}^{n_{con}},\ y \in \mathbb{Z}^{n_{int}},\ n_{con},\ n_{int} \in \mathbb{N})$$

$$\begin{aligned} \text{subject to:} \quad g_i(x,y) &= 0, \quad i = 1,...,m_e \in \mathbb{N} \\ g_i(x,y) &\geq 0, \quad i = m_e+1,...,m \in \mathbb{N} \\ x_l \leq x &\leq x_u \quad (x_l,\ x_u \in \mathbb{R}^{n_{con}}) \\ y_l \leq y &\leq y_u \quad (y_l,\ y_u \in \mathbb{N}^{n_{int}}) \end{aligned}$$

Where *f(x)* is the objective function to be minimized and *g(x)* represent the equality and inequality constraints. There are no restrictions (such as convexity or differentiability) on the functions *f(x)* and *g(x)*. The vector of continuous decision variables is denoted by ***x***, the vector of integer/discrete decision variables is denoted as ***y***. The decision variables are subject to some upper and lower bounds. Note that this class of problems is *NP-Hard*.

MIDACO Algorithm

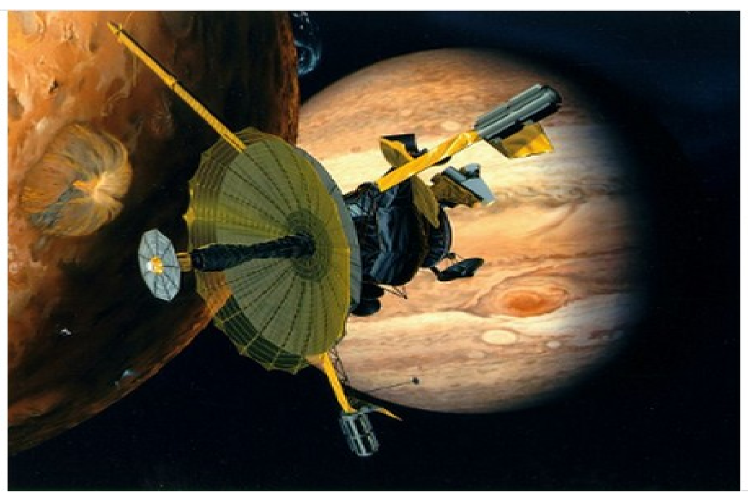
MIDACO implements an extended **Ant Colony Optimization (ACO)** algorithm, which belongs to the class of **evolutionary meta-heuristics**. The ACO algorithm is based on multi-kernel gaussian probability density functions (PDF's), which can be discretized for integer (IP) and mixed integer (MINLP) problems. In order to handle constraints, MIDACO combines the ACO algorithm with the **Oracle Penalty Method**, which is a self-adaptive and advanced approach. A graphical illustration of the Oracle Penalty Method and the continuous and discretized ACO PDF's is given below:



Continuous (left) and discretized (right) multi-kernel gaussian probability density functions (Gauss PDF's)

As an evolutionary algorithm, MIDACO does not require gradients or smooth function properties for *f(x)* and *g(x)*. MIDACO aims on finding the global optimal solution, by constantly applying internal restarts and broad search heuristics. However, being a heuristic algorithm, MIDACO can not guarantee global optimality. The MIDACO algorithm is implemented via reverse communication and features the parallelization option for the objective and constraint functions. This **parallelization** feature can be very useful for real-world applications, where the evaluation time for the problem functions is a critical issue.

Real-World Applications


MIDACO has been developed especially for the **space and aerospace** sector, but its general methodology allows its application in many industrial and academic areas. The below table lists some of the applications solved by MIDACO.

Area	Application	Author(s)
Space	Interplanetary Space Mission (NASA Galileo)	Schlueter et al.
Space	Space Launch Vehicle (Boeing Delta III)	Schlueter et al.
Space	Thermal Insulation System (Heat Shield)	Schlueter et al.
Space	Satellite Constellation	Takano, Marchand
Electr-Eng	Control of Cogeneration Systems	Pandurangan
Robotics	Optimal Camera Placement	Hänel et al.
Climate	Nonlinear Model Predictive Control	Booij, Sijs, Fransman
Finance	Distance-to-Default	Allugundu, Kumar
Finance	Application of Sales Forecasting	Comas
Bio-Tech	Parameter optimization in Bio-Technology	Rehberg et al.
Telecom	Cooperative Wireless Networks	Baidas, MacKenzie
Navy	Structural Optimization of Submarine Hulls	Wong

Space Benchmark Records

MIDACO currently holds the **best known solution** to three out of seven **difficult** space mission global optimization benchmark problems provided by the ACT-Department of the **European Space Ageny (ESA)**:

Name	Description	MIDACO Solution
GTOC1	Multiple gravity assist trajectory to asteroid TW229	-1,581,950
Cassini2	Deep space maneuver mission to Saturn	8.383
Messenger	Resonant fly-by space mission to Mercury	2.104

MIDACO User & Collaborations

Academic (selected)	**Commercial** (selected)
Beijing Institute of Technology (China)	InuTech GmbH (Germany)
ESPCI ParisTech (France)	Klaus Schittkowski Software (Germany)
Georgia Institute of Technology (USA)	Astos Solutions GmbH (Germany)
Max Planck Institut Magdeburg (Germany)	Multiscale Design System, LLC (USA)
TNO Delft (Netherlands)	MT-Aerospace (Germany)
University of Massachusetts (USA)	PACE Aerospace (Germany)
University of Rhode Island (USA)	useblocks GmbH (Germany)
Virginia Tech (USA)	Britton Industries, LLC (USA)

References & Acknowledgment

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