AToM

ANTENNA TOOLBOX FOR MATLAB

CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF ELECTRICAL ENGINEERING
DEPARTMENT OF ELECTROMAGNETIC FIELD
TECHNICKÁ 2, 166 27 PRAHA 6 – DEJVICE
CZECH REPUBLIC

www.antennatoolbox.com info@antennatoolbox.com +420 224352280

CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF ELECTRICAL ENGINEERING
DEPARTMENT OF ELECTROMAGNETIC FIELD
TECHNICKÁ 2, 166 27 PRAHA 6 – DEJVICE
CZECH REPUBLIC

Optimization tool FOPS

P. Kadlec, M. Marek, M. Cupal

Brno University of Technology

petr.kadlec@antennatoolbox.com

Outline

- Motivation
- Metaheuristics in general
- FOPS – features
- FOPS – architecture
- Examples
- Future work

CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF ELECTRICAL ENGINEERING
DEPARTMENT OF ELECTROMAGNETIC FIELD
TECHNICKÁ 2, 166 27 PRAHA 6 – DEJVICE
CZECH REPUBLIC

Motivation

Always try to do the best…

- optimal antenna design[1]
- knowing characteristic modes -> optimal feeding
- common habit of commercial solvers
- combining good features of different methods
- comparison of new optimization methods

[1] M. Gustafsson, M. Cismasu and B. L. G. Jonsson, "Physical Bounds and Optimal Currents on Antennas," in *IEEE Transactions on Antennas and Propagation*, vol. 60, no. 6, pp. 2672-2681, June 2012.

doi: 10.1109/TAP.2012.2194658

CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF ELECTRICAL ENGINEERING
DEPARTMENT OF ELECTROMAGNETIC FIELD
TECHNICKÁ 2, 166 27 PRAHA 6 – DEJVICE
CZECH REPUBLIC

Metaheuristics in general

Problem formulation

$$
\begin{aligned}
&\textit{Minimize} \quad F_m(\mathbf{x}), && m = 1, 2, \ldots, M, \\
&\textit{subject to} \quad g_j(\mathbf{x}) \geq 0, && j = 1, 2, \ldots, J, \\
&x_{n,\min} \leq x_n \leq x_{n,\max}, && n = 1, 2, \ldots, N.
\end{aligned}
$$

F_m - *m*-th objective function,

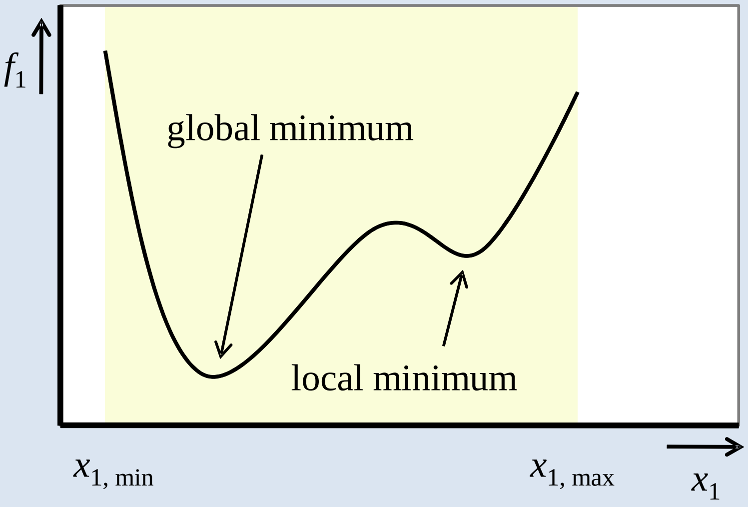
x - decision space (variables, parameter) vector

g_j - *j*-th constraint condition

$x_{n,\min}$, $x_{n.\max}$ - lower and upper bound of *n*-th variable

Metaheuristics in general

Global vs. Local methods



Local methods:

- good initial guess
- fast and accurate
- tend to local minimum
- derivatives or differences

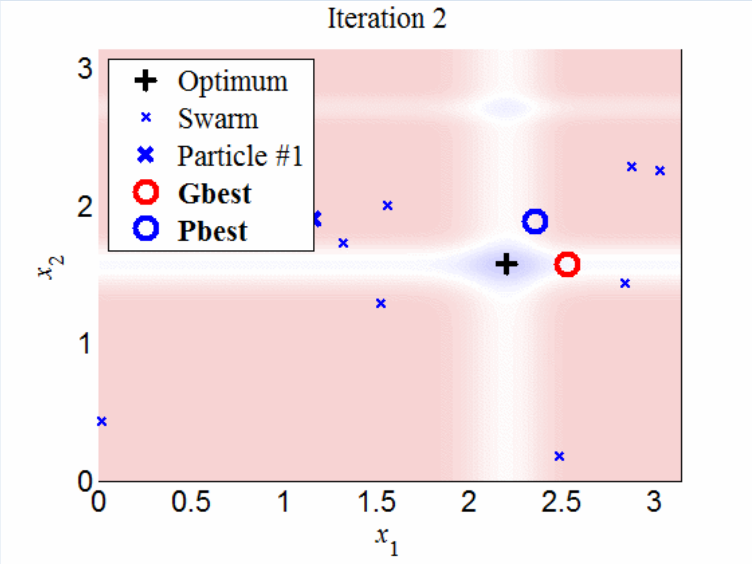
Global methods:

- fixed bounds of variables
- brute force
- get out of local minimum
- no information about objective functions

CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF ELECTRICAL ENGINEERING
DEPARTMENT OF ELECTROMAGNETIC FIELD
TECHNICKÁ 2, 166 27 PRAHA 6 – DEJVICE
CZECH REPUBLIC

Metaheuristics in general

General Pseudocode of Global Methods



Random individuals generation (solution)
Objective function evaluation
While *stop condition*
    Propose new individuals
    Objective function evaluation
End
Best solution assignment

CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF ELECTRICAL ENGINEERING
DEPARTMENT OF ELECTROMAGNETIC FIELD
TECHNICKÁ 2, 166 27 PRAHA 6 – DEJVICE
CZECH REPUBLIC

FOPS Features

FOPS = Fast Optimization ProcedureS

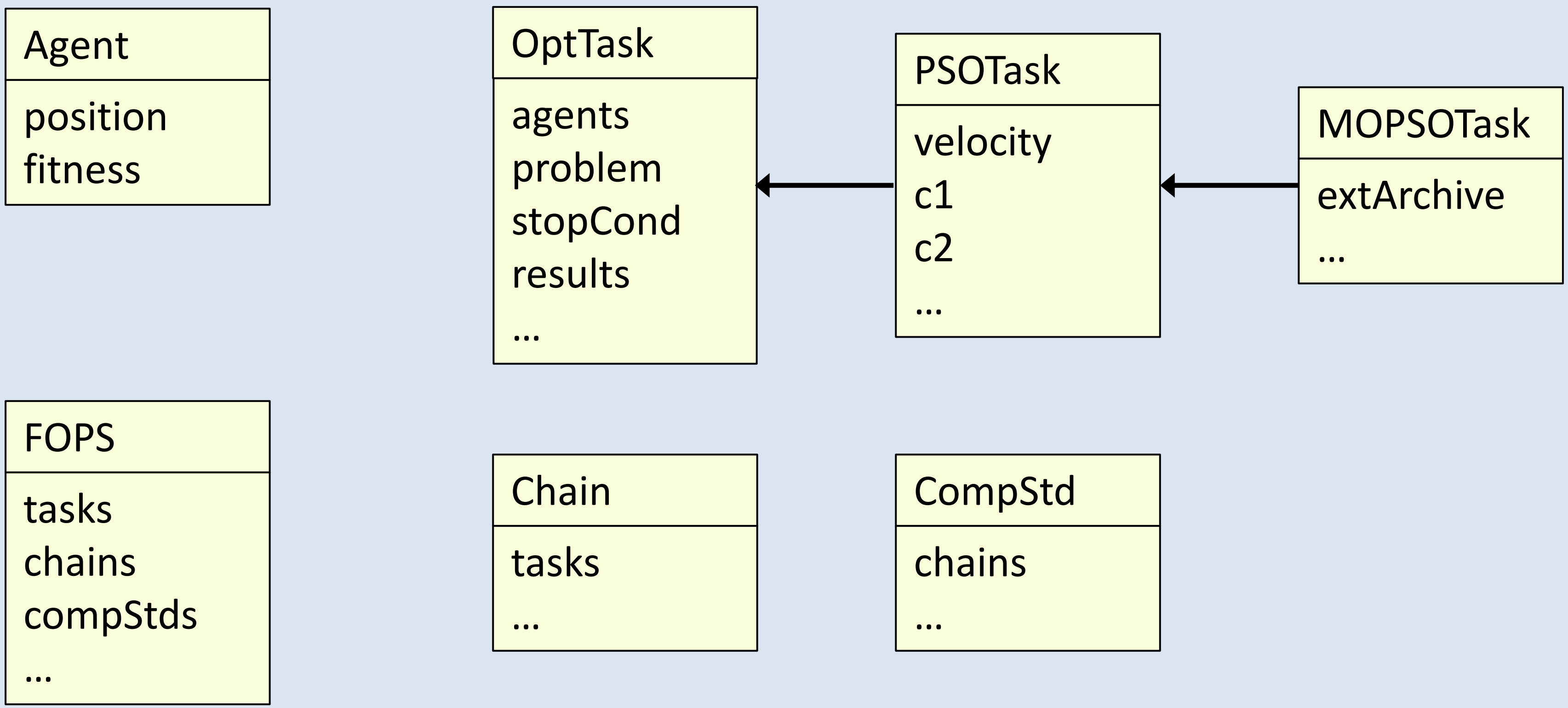
- local methods: steepest descent, Newton method
- global methods: Nelder Mead, GA, PSO, DE, SOMA …
- single- and multiobjective codes
- chains from individual methods
- user defined problems
- gallery of benchmark problems
- comparative tool

CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF ELECTRICAL ENGINEERING
DEPARTMENT OF ELECTROMAGNETIC FIELD
TECHNICKÁ 2, 166 27 PRAHA 6 – DEJVICE
CZECH REPUBLIC

ATоM
ANTENNA TOOLBOX FOR MATLAB

FOPS Architecture

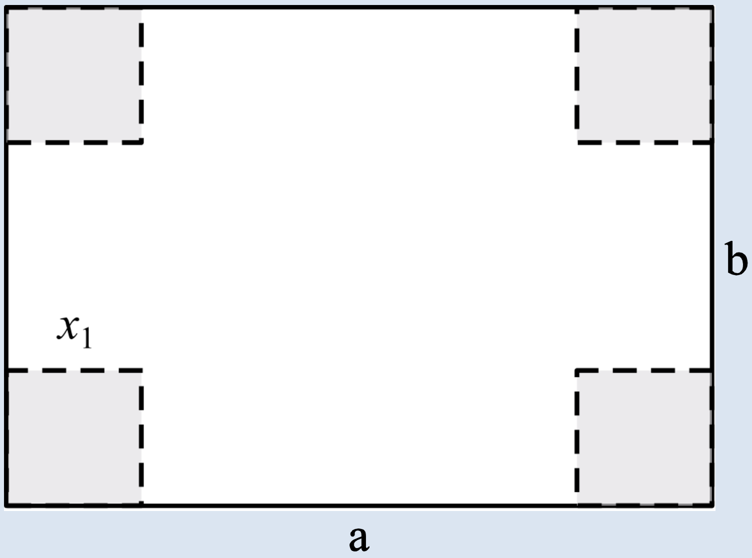
Object Oriented Programming



CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF ELECTRICAL ENGINEERING
DEPARTMENT OF ELECTROMAGNETIC FIELD
TECHNICKÁ 2, 166 27 PRAHA 6 – DEJVICE
CZECH REPUBLIC

Example 1

Box with maximal volume - singleobjective



$$f_1 = -\left(4x_1^3 - \left(2a + 2b\right)x_1^2 + abx_1\right)$$

$$a = 275, b = 210$$

$$x_{1,1} = 122.32, x_{1,2} = 39.34,$$

$$f\left(x_{1,1}\right) = 1.29 \cdot 10^5,$$

$$f\left(x_{1,2}\right) = -1.01 \cdot 10^6$$

Example 1

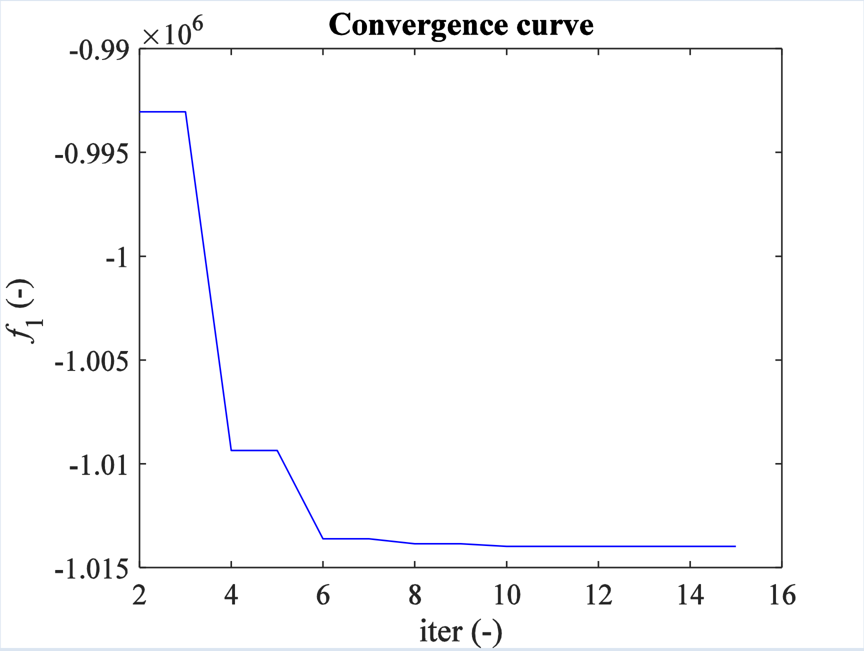
FOPS solution using default SOPSO

```
fops = FOPS();

problem = struct('limits', [1; 105], ...
 'fitness', @(x) boxVolume(x), ...
 'isVectorized', true, ...
 'name', 'myProblemBox');

fops.addTask({problem}, {'SOPSO'});

fops.runTasks; % fops.runTask('myProblemBox')

function [f] = boxVolume(x)
   a = 275;
   b = 210;
   f(:, 1) = -(4*x(:,1).^3 - (2*a+2*b)*x(:,1).^2 + a*b*x(:,1));
end
```

CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF ELECTRICAL ENGINEERING
DEPARTMENT OF ELECTROMAGNETIC FIELD
TECHNICKÁ 2, 166 27 PRAHA 6 – DEJVICE
CZECH REPUBLIC

Example 1

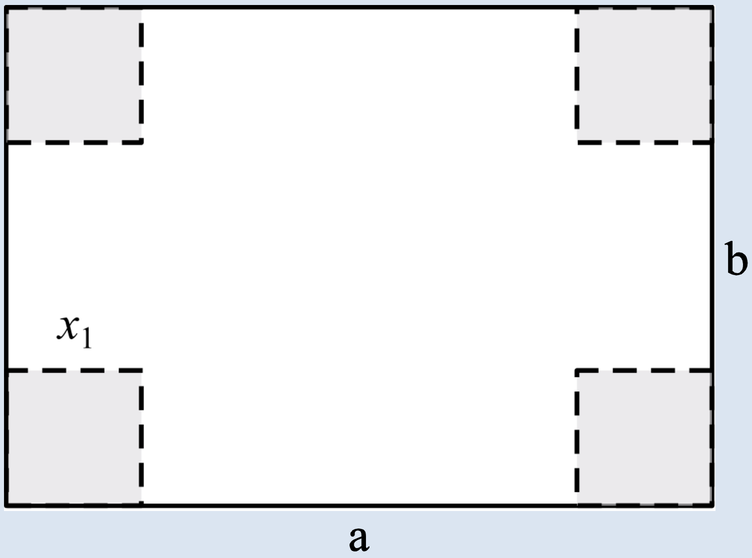
Results




```
...
fops.runTasks;

fops.resultFitness

   ans = -1014184

fops.resultX

   ans = 39.34
```

Example 2

Box - max volume and min waste



$$f_1 = -\left(4x_1^{\;3} - \left(2a+2b\right)x_1^{\;2} + abx_1\right),$$

$$f_2 = 4x_1^{\;2},$$

$$a = 275,$$

$$b = 210$$

Example 2

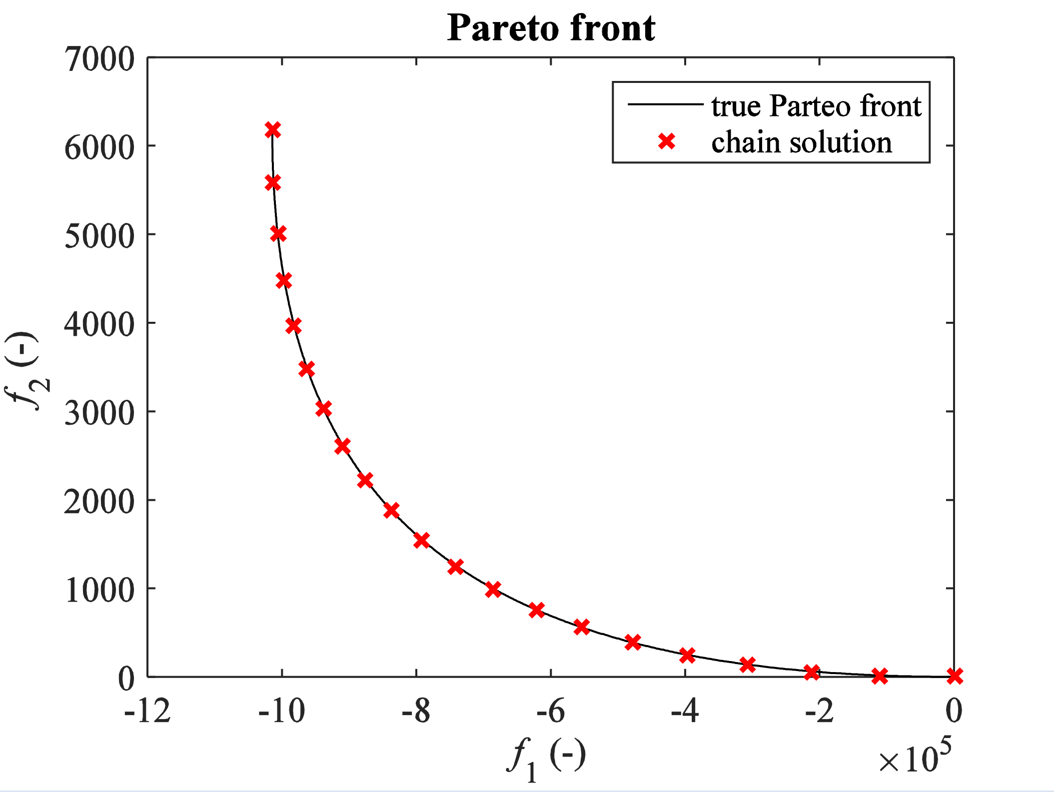
FOPS solution using chain NSGA-II - MOPSO

```
fops = FOPS();

problem = struct('limits', [0; 105], 'fitness', @(x) boxVolume(x), ...
 'isVectorized', true, 'name', 'myProblemBoxMO');

psoSettings = struct('nIters', 10, 'W', 0.7, 'C2', 1.9);

fops.addChain({problem}, {'NSGAII', 'MOPSO'}, {[], psoSettings});
fops.runChains;

function [f] = boxVolume(x)
   a = 275;
   b = 210;
   f(:, 1) = -(4*x(:,1).^3 - (2*a+2*b)*x(:,1).^2 + a*b*x(:,1));
   f(:, 2) = 4*x(:,1).^2;
end
```

CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF ELECTRICAL ENGINEERING
DEPARTMENT OF ELECTROMAGNETIC FIELD
TECHNICKÁ 2, 166 27 PRAHA 6 – DEJVICE
CZECH REPUBLIC

Example 2

Results of chain NSGA-II - MOPSO



Example 3

Comparative study

```
fops = FOPS();

fops.addCompStudy(10, ... % nRuns
    {'MOZDT1'; 'MOFON'; 'MOZDT3'}, ... % problems
    {'Delta'; 'GD'; 'HV'}, ... % requests
    {'NSGAII'; ... % algorithms: chain1
    'MOPSO'; ...  % algorithms: chain2
    'NSGAII', 'MOPSO'});  % algorithms: chain3

fops.runCompStudies;
```

CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF ELECTRICAL ENGINEERING
DEPARTMENT OF ELECTROMAGNETIC FIELD
TECHNICKÁ 2, 166 27 PRAHA 6 – DEJVICE
CZECH REPUBLIC

Example 3

Comparative study - tables of specified metrics

GD: 3x3 table =

	NSGA_II	MOPSO	Chain
MOZDT1	'1.83e-01'	'2.28e-01'	'1.24e-02'
MOFON	'2.71e-03'	'7.82e-05'	'7.37e-05'
MOZDT3	'1.19e-01'	'2.43e-01'	'9.53e-03'

Delta: 3x3 table =

	NSGA_II	MOPSO	Chain
MOZDT1	'6.11e-01'	'4.11e-01'	'1.46e-01'
MOFON	'1.57e-01'	'1.18e-01'	'1.12e-01'
MOZDT3	'6.38e-01'	'7.44e-01'	'3.13e-01'

HV: 3x3 table =

	NSGA_II	MOPSO	Chain
MOZDT1	'4.05e-01'	'3.74e-01'	'6.44e-01'
MOFON	'3.31e-01'	'3.37e-01'	'3.37e-01'
MOZDT3	'5.82e-01'	'4.54e-01'	'8.21e-01'

CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF ELECTRICAL ENGINEERING
DEPARTMENT OF ELECTROMAGNETIC FIELD
TECHNICKÁ 2, 166 27 PRAHA 6 – DEJVICE
CZECH REPUBLIC

Summary

FOPS:

- any dimension *N*, any number of objectives *M* and constraints *g*
- SOOP / MOOP
- job manager
- chaining of methods
- comparative tool (benchmark functions, metrics)

Planned work:

- GUI
- more methods
- variable number of dimensions

CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF ELECTRICAL ENGINEERING
DEPARTMENT OF ELECTROMAGNETIC FIELD
TECHNICKÁ 2, 166 27 PRAHA 6 – DEJVICE
CZECH REPUBLIC

THANK YOU

FOR YOUR ATTENTION

www.antennatoolbox.com
info@antennatoolbox.com
petr.kadlec@antennatoolbox.com

SUPPORTED BY