AToM

ANTENNA TOOLBOX FOR MATLAB

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Optimization tool FOPS

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Outline

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

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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.

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Metaheuristics in general

Problem formulation

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

F_m - *m*-th objective function,

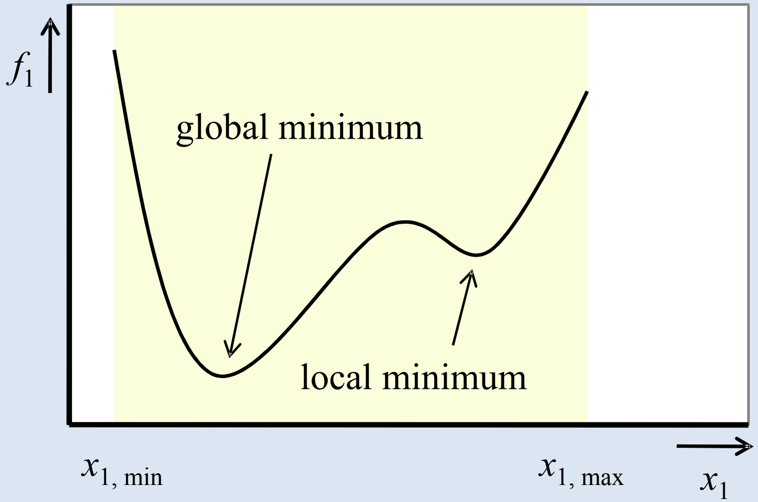
$\mathbf{x}$ - decision space (variables, parameter) vector

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

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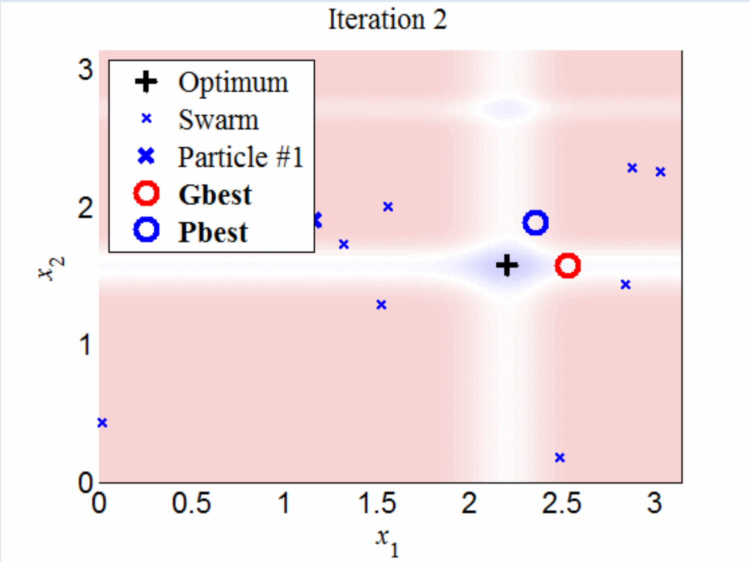
Metaheuristics in general

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

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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

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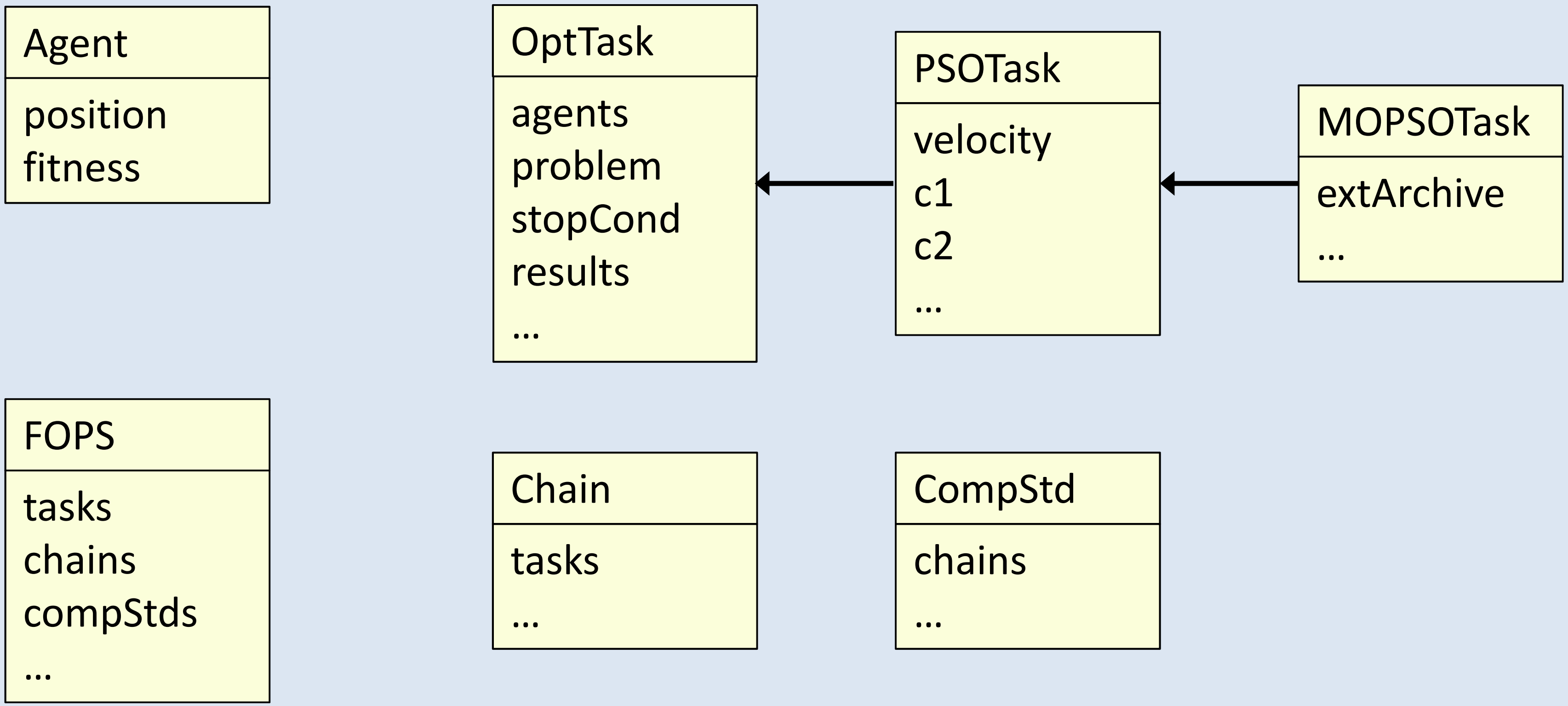
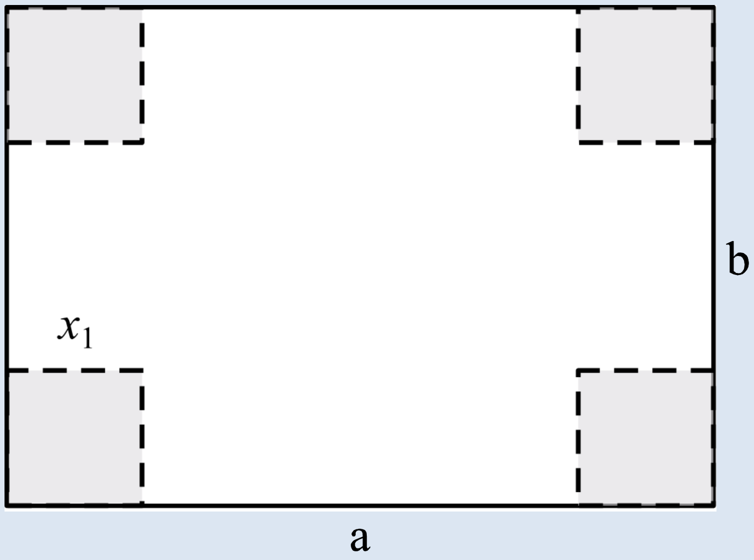
FOPS Architecture

Object Oriented Programming



Example 1

Box with maximal volume - singleobjective



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

$$a = 275, b = 210$$

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

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

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

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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
```

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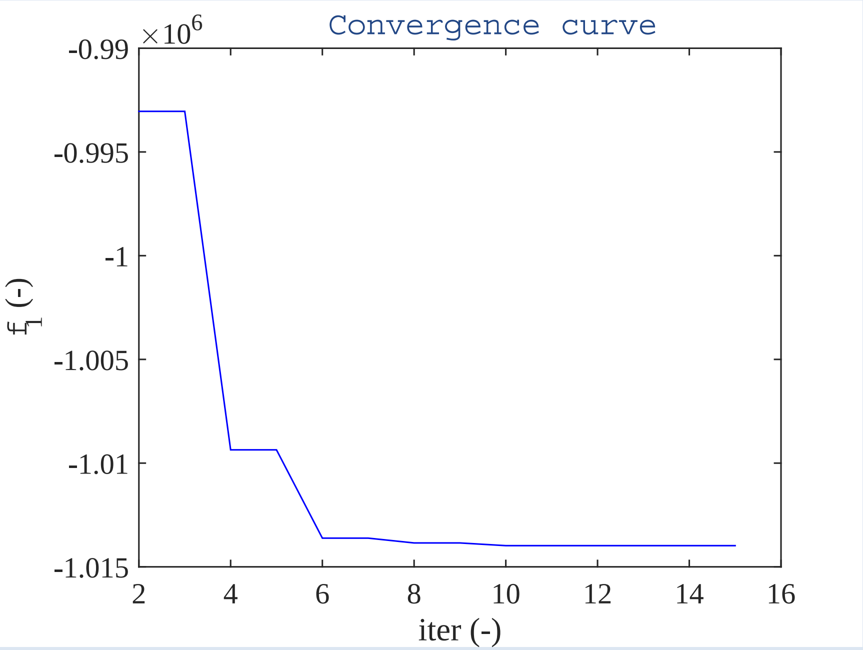
Example 1

Results




```
...
fops.runTasks;

fops.resultFitness

   ans = -1014184

fops.resultX

   ans = 39.34
```

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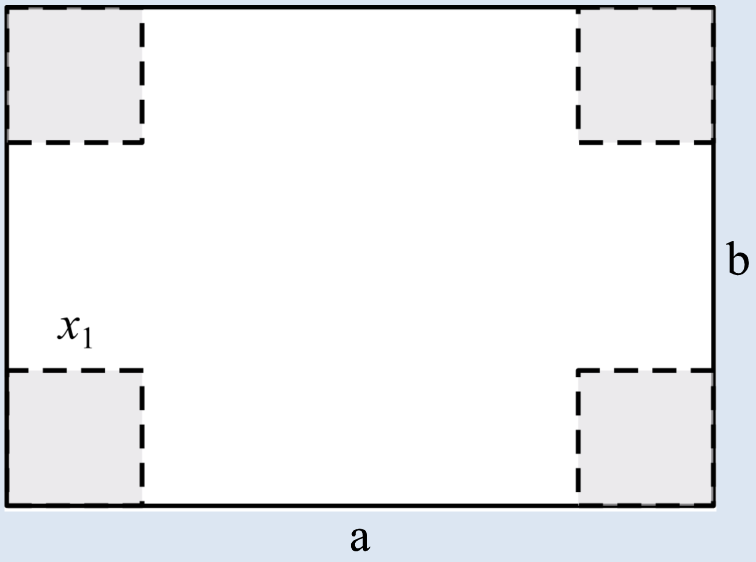
Example 2

Box - max volume and min waste



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

$$f_2 = 4x_1^2,$$

$$a = 275,$$

$$b = 210$$

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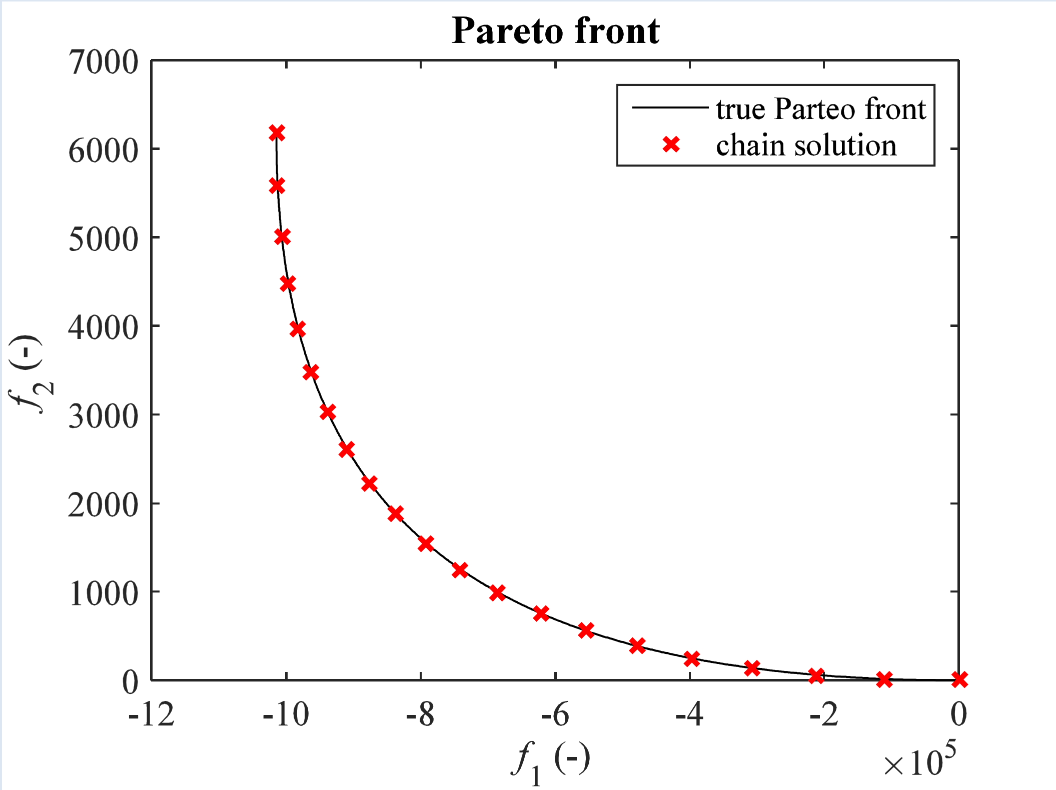
Example 2

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
```

Example 2

Results of chain NSGA-II - MOPSO



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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;
```

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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'

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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

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