An interface between MATLAB and SIPAMPL for semi-infinite programming problems

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• Semi-Infinite Programming (SIP)
• SIPAMPL environment
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Semi-Infinite Programming

\[
\min_{x \in \mathbb{R}^n} f(x)
\]

s.t. \( g_i(x, t) \leq 0, \ i = 1, \ldots, m \)

\( h_i(x) \leq 0, \ i = 1, \ldots, o \)

\( h_i(x) = 0, \ i = o + 1, \ldots, q \)

\( \forall t \in T \)

\( f(x) \) is the objective function, \( h_i(x) \) are the finite constraint functions, \( g_i(x, t) \) are the infinite constraint functions and \( T \subset \mathbb{R}^p \) is, usually, a cartesian product of intervals

\(([\alpha_1, \beta_1] \times [\alpha_2, \beta_2] \times \cdots \times [\alpha_p, \beta_p])\)
SIPAMPL environment - Motivations

SIPAMPL was developed four years ago with the following proposes:

- To allow an easy and fast way to code SIP problems, using a (SIP)AMPL format
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- To allow an easy and fast way to code SIP problems, using a (SIP)AMPL format
- To allow the interface between the coded problems and any solver
- To use AMPL software for automatic differentiation and its modeling language
- To provide a database with semi-infinite programming problems (to the image of AMPL or CUTE for finite problems)
SIPAMPL today

- More than 160 SIP problems coded

SIPAMPL is publicly available in http://www.norg.uminho.pt/aivaz/
SIPAMPL today

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- Dynamic B- and C-Splines library (robotics problems)

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- Interface routines between MATLAB and SIPAMPL routines
- Select tool

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SIPAMPL and a SIP solver interaction

AMPL

.nl file
.col file
.row file

AMPL interface routines

AMPL

.sol file

SIPAMPL interface routines

SIP solver

finite solver

MATLAB to SIPAMPL interface routines

MATLAB solver
**Example of SIP problem** (*hettich2*)

Approximation problem of $t^2$ by a combination of $t$ and $e^t$. $d$ is the minimum distance.

\[
\min_{p,d \in \mathbb{R}^{2+1}} d \\
\text{s.t. } |t^2 - (p_1 t + p_2 e^t)| - d \leq 0 \\
\forall t \in [0, 2]
\]
Problem solution

\[ 0.186829t + 0.417929e^t \]

\[ d^* = 0.538242 \]
Example coded in AMPL ((SIP)AMPL format)

##########################################################################
# Objective: Linear
# Constraints: Linear
##########################################################################
# Hettich set of SIP problems (Chebyshev approximation problems)
# As described by R. Hettich, "A comparison of some numerical methods
# for semi-infinite programming",
# in R. Hettich (eds.), "Semi-infinite Programming",
# Lecture notes in Control and Information Sciences no. 15, pp. 112-125
# Springer Verlag, Berlin (1979)
#
# Example 2
# Coded by A. Ismael F. Vaz 27/12/1999 aivaz@dps.uminho.pt
# University of Minho, Portugal
##########################################################################
var p {1..2};
var t {1..1};
var d;
minimize dp:
   d;

subject to tcons1:
   -(t[1]^2-(p[1]*t[1]+p[2]*exp(t[1]))) - d <= 0;

subject to tcons2:
   (t[1]^2-(p[1]*t[1]+p[2]*exp(t[1]))) - d <= 0;

subject to bounds {i in 1..1}:
   0 <= t[i] <= 2;

# don’t forget to write .col and .row files
option nsips_auxfiles rc;
# this problem has no initial guess (starting point)
option reset_initial_guesses 1;
# change solver
option solver nsips;
# solve problem
solve;
printf "Solution found\n";
display p;
display dp;

# solution of problem presented by the authors
printf "Original Solution\n";
printf "p=(%lf,%lf) dp=%lf\n", 0.184, 0.418, 0.538;
**MATLAB fseminf function**

The MATLAB \texttt{fseminf} syntax is:

\[
[x,fval,exitflag,output,lambda]=
\texttt{fseminf}('mysipfun',x0,ntheta,'mysipcon',A,b,
Aeq,beq,lb,ub,options,P1,P2,...).
\]

**Output arguments:**

- \texttt{x} - solution found;
- \texttt{fval} - objective value at \texttt{x};
- \texttt{exitflag} - exit condition of the algorithm;
- \texttt{output} - structure with algorithm information;
- \texttt{lambda} - Lagrange multipliers.
MATLAB \texttt{fseminf} function

The MATLAB \texttt{fseminf} syntax is:

\[
[x,fval,exitflag,output,lambda]=\]

\[
fseminf('mysipfun',x0,ntheta,'mysipcon',A,b, \]

\[
Aeq,beq,lb,ub,options,P1,P2,...)\].

Input arguments:

- \texttt{mysipfun} - objective function;

  \[
  \text{function } [f,g] = mysipfun(x) \]

  where \( f \) and \( g \) are the objective function and gradient at \( x \);
Input arguments:

- $x_0$ - initial guess;
- $n_{\text{theta}}$ - number of infinite constraints;
- $\text{mysipcon}$ - constraints function;

$$\text{function } [c,ceq,K_1,K_2,\ldots,K_{n_{\text{theta}}},s] = \text{mysipcon}(x,s)$$

where $c$ and $ceq$ are the finite inequality and equality constraints at $x$, $K_1$, $\ldots$, $K_{n_{\text{theta}}}$ are vectors or matrices with the infinite constraints evaluated at an equally spaced ($s$) grid of points.

- $A$, $b$, $A_{\text{eq}}$ and $b_{\text{eq}}$ - inequality and equality linear constraints;
- $lb$ and $ub$ - lower and upper bounds on $x$;
- $\text{options}$ - options to the algorithm;
- $P_1$, $P_2$, $\ldots$ - extra arguments.
MATLAB solver

- The user has to define the MATLAB functions to provide the objective, objective gradient and constraints function values;
MATLAB solver

- The user has to define the MATLAB functions to provide the objective, objective gradient and constraints function values;

- The user defines an initial sampling interval \((s)\) for the infinite constraints and the constraints function returns \(K_1, K_2, \ldots, K_{n\theta}\) vectors or matrices, which are the infinite constraints evaluated at an equally spaced grid of points.
MATLAB solver

- The user has to define the MATLAB functions to provide the objective, objective gradient and constraints function values;

- The user defines an initial sampling interval \((s)\) for the infinite constraints and the constraints function returns \(K_1, K_2, \ldots, K_{n\theta}\) vectors or matrices, which are the infinite constraints evaluated at an equally spaced grid of points.

Since MATLAB expects \(K_i\) to be vectors or matrices, the use of SIPAMPL by MATLAB is limited to problems with 2 infinite constraints.
The MATLAB algorithm

• A quasi-Newton SQP algorithm with line search and a merit function;
The MATLAB algorithm

- A quasi-Newton SQP algorithm with line search and a merit function;

- Identifies peaks in the discretized constraints function values and applies a quadratic or cubic interpolation to obtain an estimate of the maxima in the constraints;
The MATLAB algorithm

- A quasi-Newton SQP algorithm with line search and a merit function;

- Identifies peaks in the discretized constraints function values and applies a quadratic or cubic interpolation to obtain an estimate of the maxima in the constraints;

- Since the number of maxima can change during the iterative process, the Lagrange multipliers are reallocated to the new set of maxima.
MATLAB interface with SIPAMPL

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sip_init</td>
<td>initialize and</td>
</tr>
<tr>
<td>sip_end</td>
<td>stops the SIPAMPL interface routines</td>
</tr>
<tr>
<td>sip_objval</td>
<td>objective function value, gradient and Hessian</td>
</tr>
<tr>
<td>sip_contval</td>
<td>infinite constraint value, gradient and Hessian</td>
</tr>
<tr>
<td>sip_conxeqval</td>
<td>finite equality constraint value, gradient and Hessian</td>
</tr>
<tr>
<td>sip_conxineqval</td>
<td>finite inequality constraint value, gradient and Hessian</td>
</tr>
<tr>
<td>sip_jacval</td>
<td>values of all Jacobians</td>
</tr>
<tr>
<td>sip_usage</td>
<td>usage of all the described functions</td>
</tr>
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</table>
Example of MATLAB objective function

function [f,g]=mysipfun(x,s)

if nargin < 1 | nargout<1
    error('Invalid number of arguments');
end

f=sip_objval(x);
if nargout > 1
    g=sip_objgrd(x);
end
Example of MATLAB constraint function

function [c,ceq,K1,K2,s]=mysipcon(x,s)
if nargin < 2 | nargout<5
    error('Invalid number of arguments');
end
if isnan(s(1,1)),
    s=[0.2 0; 0.2 0];
end
w1=1:s(1,1):100;
w2=1:s(2,1):100;
lw1=length(w1);
lw2=length(w2);
K1=zeros(lw1,1);
K2=zeros(lw2,1);
for i=1:lw1
    K1(i)=sip_contval(0,x,w1(i));
end
for i=1:lw2
    K2(i)=sip_contval(1,x,w2(i));
end
c=[]; ceq=[];
plot(w1,K1,'-',w2,K2,:)','
title('Semi-infinite constraints')
drawnow
A simple run

After producing the `matlab1.nl`, `matlab1.col`, `matlab1.row` (for SIPAMPL interface routines).

```matlab
>> [x0, xbl, xbu, tbl, tbu]=sip_init('matlab1');
>> [x, fval]=fseminf('mysipfun',x0,2,'mysipcon')
Optimization terminated successfully:
   Search direction less than 2*options.TolX and
   maximum constraint violation is less than
   options.TolCon
Active Constraints:
   7
   10
x' = 0.6673  0.3013  0.4023
fval = 0.0770
```
Test problems

Using the SIPAMPL Select tool to obtain the problems (files) names and the corresponding .nl files.
Test problems

Using the SIPAMPL Select tool to obtain the problems (files) names and the corresponding .n1 files.

The Select tool can optionally provide a shell script, batch and m-file to run all the problems.
Test problems

Using the SIPAMPL Select tool to obtain the problems (files) names and the corresponding .nl files.

The Select tool can optionally provide a shell script, batch and m-file to run all the problems.

Problems with at most two infinite variables.
## Selected problems

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<th>nt</th>
<th>nxc</th>
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<th>Problem</th>
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# Selected problems

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1. These problems were solved with a different solver.
2. These problems were solved with a different implementation of the same solver.
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Plotting

The SIPAMPL interface routines also provide a great help in plotting.

Air pollution control problem vaz1.mod
Conclusions

• SIPAMPL provides several coded SIP problems;
Conclusions

- SIPAMPL provides several coded SIP problems;
- SIPAMPL provides an interface between MATLAB and AMPL, allowing SIP problems coded in AMPL to be solved by MATLAB;
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Conclusions

- SIPAMPL provides several coded SIP problems;
- SIPAMPL provides an interface between MATLAB and AMPL, allowing SIP problems coded in AMPL to be solved by MATLAB;
- MATLAB provides a solver for SIP;
- Numerical results shown with the MATLAB fseminf solver;
The End

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    emgpf@dps.uminho.pt
Web  http://www.norg.uminho.pt/aivaz/