

Optidef

A Latex library for minimization/maximization
problems definition

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1 Introduction and features

This small library provides a standard set of environments for writing minimization problems. The most important features are:

1. It automatically aligns the problems in three points with an optional fourth:
 - (a) Beginning of the words "minimize/argmin" and "subject to"
 - (b) The objective function and the longest left hand side of the constraints
 - (c) The $=$ $>$ $<$ signs of the constraints.
 - (d) Optionally, the user can add manually a double align character $\&\&$ to align some common constraints feature. A clear example could be the constraints names, e.g. (boundary constraint) alignment with (dynamic constraint), or the index of the constraints, e.g. in the case of having something like $h(x_k, u_k) \leq 0, \quad k = 0, \dots, N$, align the indexes $k = 0, \dots, N$ across constraint lines.
2. It provides an easy interface to define optimization problem for three different reference situations:
 - (a) Where no equation is referenced/numbered.
 - (b) Where the problem is referenced with a single number.
 - (c) Where each equation has an individual reference.
3. It also allows a definition of any optimization problem without a limitless number of constraints.

2 Environment types

There are three basic environments depending on the type of referencing that should be used.

1. The **mini** environment for defining problems with a single reference label:

$$\begin{array}{ll} \underset{w}{\text{minimize}} & f(w) + R(w + 6x) + \nabla_w R \\ \text{subject to} & g(w) = 0 \end{array} \tag{1}$$

2. The **mini*** environment if the problem does not have to be referenced:

$$\begin{array}{ll} \underset{w}{\text{minimize}} & f(w) + R(w + 6x) + \nabla_w R \\ \text{subject to} & g(w) = 0 \end{array}$$

3. The **mini!** environment if each equation should be referenced:

$$\underset{w}{\text{minimize}} \quad f(w) + R(w + 6x) + \nabla_w R \tag{2a}$$

$$\text{subject to} \quad g(w) = 0 \tag{2b}$$

3 Environment Syntaxes

The three environments use the same syntax with the same number of parameters. In particular, considering that LHS stands for Left-hand-side and RHS for Right-hand-side, the basic structure to define a general optimization problem is:

```
\begin{mini#}{Number of constraints}
  {Optimization variable}
  {Objective function \label{Objective function referece}}
  {LHS Constraint 1}{RHS Constraint 1 \label{Reference Constraint 1}}
  {\label{Global referece of Optimization Problem}}
  {Result of the optimization problem or any expression on
the left of the minimize word}

  \addConstraint{LHS Constraint 2}{RHS Constraint 2 \label{Reference Constraint 2}}
  \addConstraint{LHS Constraint 3}{RHS Constraint 3 \label{Reference Constraint 3}}
  .
  .
  \finalConstraint{LHS N} {RHSConstraint N \label{Reference Constraint N}}
\end{mini#}
```

where $\# \in \{*,!, \}$.

3.1 Parameters definition

The number of parameters that the environment uses is 7:

1. Number of constraints, e.g. 0,1,2,3,4...
2. Optimization variable, e.g. $w \in \mathbb{R}^N$.
3. Objective function, e.g. $\|w\|_2$.
4. LHS Constraint 1 (optional): the left-hand side of the first constraint, e.g. $3w^\top w$. For unconstrained problems leave it blank, i.e. $\{\}$
5. RHS Constraint 1 (optional): the right-hand side of the first constraints including the equal, less and greater signs, e.g. $\leq \|w\|_\infty$. For unconstrained problems leave it blank, i.e. $\{\}$
6. `\label{Global referece of Optimization Problem}`: it defines the main and general reference for the optimization problem. It is used for the `mini` and `mini!` enviroments. In the `mini*` environment leave it blank, i.e. $\{\}$.
7. Result of the optimization problem: optionally a term expressing the result of the optimization problem, e.g. $J(w^*) =$.

Notice that only the first three will be really necessary in every definition, nevertheless and for the sake of having homogeneous definitions, we opted for requiring the 7 parameters in every definition and expecting empty parameters definitions, i.e. {}, when they are not needed.

After the definition of this parameters, the environment accepts the definition of an infinite number of constraints. For this definitions the command:

```
\addConstraint{LHS Constraint k}
{RHS Constraint k \label{Reference Constraint k}}
```

has to be used, where the left hand side and right hand side syntax is the same as used for the mandatory third and fourth environment parameters.

Notice that the last constraint has to be defined using the `\finalConstraint` command, instead of the `\addConstraint`.

Constraints referencing

Notice that the label for the constraints is always included in the right hand side expression and it only makes sense for the case of using the `mini!` environment. The label of the objective function can also be included in a similar way.

Example 1 - mini environment

The code:

```
\begin{mini}{4}
{w}{f(w)+ R(w+6x) + \nabla_w R}
{g(w)}{=0}

{\label{eq:Example1}}
{}

\addConstraint{n(w)}{= 6}
\addConstraint{L(w)+r(x)}{=Kw+p}
\finalConstraint{h(x)}{=0.}
\end{mini}
```

outputs:

$$\begin{aligned}
& \underset{w}{\text{minimize}} && f(w) + R(w + 6x) + \nabla_w R \\
& \text{subject to} && g(w) = 0, \\
& && n(w) = 6, \\
& && L(w) + r(x) = Kw + p, \\
& && h(x) = 0.
\end{aligned} \tag{3}$$

Example 2 - mini* environment

On the other hand:

```

\begin{mini*}{4}
  {w}{f(w)+ R(w+6x) + \nabla_w R}
  {g(w)}{=0,}

  {}{}

  \addConstraint{n(w)}{= 6,}
  \addConstraint{L(w)+r(x)}{=Kw+p}
  \finalConstraint{h(x)}{=0.}
\end{mini*}

```

it is almost the same but removing the reference:

$$\begin{aligned}
 & \underset{w}{\text{minimize}} && f(w) + R(w + 6x) + \nabla_w R \\
 & \text{subject to} && g(w) = 0, \\
 & && n(w) = 6, \\
 & && L(w) + r(x) = Kw + p, \\
 & && h(x) = 0.
 \end{aligned}$$

Example 3 - mini! environment

Finally, the multireferencing environment outputs:

```

\begin{mini!}{4}
  {w}{f(w)+ R(w+6x) + \nabla_w R \label{eq:ObjectiveExample1}}
  {g(w)}{=0 \label{eq:C1Example1}}

  {\label{eq:Example1}}
  {}

  \addConstraint{n(w)}{= 6 \label{eq:C2Example1}}
  \addConstraint{L(w)+r(x)}{=Kw+p \label{eq:C3Example1}}
  \finalConstraint{h(x)}{=0. \label{eq:C4Example1}}
\end{mini!}

```

$$\underset{w}{\text{minimize}} \quad f(w) + R(w + 6x) + \nabla_w R \tag{4a}$$

$$\text{subject to} \quad g(w) = 0, \tag{4b}$$

$$n(w) = 6, \tag{4c}$$

$$L(w) + r(x) = Kw + p, \tag{4d}$$

$$h(x) = 0. \tag{4e}$$

Example 4 - mini + problem result

Adding the problem result:

```
\begin{mini}{4}
{w}{f(w)+ R(w+6x) + \nabla_w R}
{g(w)}{=0}

{\label{eq:Example1}}
{J(w^*)=}

\addConstraint{n(w)}{= 6}
\addConstraint{L(w)+r(x)}{=Kw+p}
\finalConstraint{h(x)}{=0.}
\end{mini}
```

outputs:

$$\begin{aligned} J(w^*) = \quad & \underset{w}{\text{minimize}} \quad f(w) + R(w + 6x) + \nabla_w R \\ & \text{subject to} \quad g(w) = 0, \\ & \quad n(w) = 6, \\ & \quad L(w) + r(x) = Kw + p, \\ & \quad h(x) = 0. \end{aligned} \tag{5}$$

Example 5 - mini* + extra constraint alignment

Adding the fourth optional alignment to add constraint names:

```
\begin{mini*}{4}
{w}{f(w)+ R(w+6x) + \nabla_w R}
{g(w)}{=0, \quad \&\& \text{(Dynamic constraint)}}

{}{}

\addConstraint{n(w)}{= 6, \quad \&\& \text{(Boundary constraint)}}
\addConstraint{L(w)+r(x)}{=Kw+p, \quad \&\& \text{(Random constraint)}}
\finalConstraint{h(x)}{=0.\quad \&\& \text{(Path constraint)}}
\end{mini*}
```

$$\begin{aligned} & \underset{w}{\text{minimize}} \quad f(w) + R(w + 6x) + \nabla_w R \\ & \text{subject to} \quad g(w) = 0, \quad (\text{Dynamic constraint}), \\ & \quad n(w) = 6, \quad (\text{Boundary constraint}), \\ & \quad L(w) + r(x) = Kw + p, \quad (\text{Random constraint}), \\ & \quad h(x) = 0. \quad (\text{Path constraint}). \end{aligned}$$

Example 6 - mini environment on the unconstrained case

```
\begin{mini}{0}
  {w}{f(w)+ R(w+6x) + \nabla_w R}
  {}{}
  {}{}
  {\label{eq:Ex4}}
  {}
\end{mini}
```

outputs:

$$\underset{w}{\text{minimize}} \quad f(w) + R(w + 6x) + \nabla_w R \quad (6)$$

4 The *argmini* environment

Similar to the `mini`, `mini*` and `mini!` environments, the environments `argmini`, `argmini*` and `argmini!` are very similar environments that use the same syntax but the output is slightly different. The following code serves for illustration:

```
\begin{argmini}{4}
  {w}{f(w)+ R(w+6x) + \nabla_w R}
  {g(w)}{=0}

  {\label{eq:Example1}}{w^*=}

  \addConstraint{n(w)}{= 6}
  \addConstraint{L(w)+r(x)}{=Kw+p}
  \finalConstraint{h(x)}{=0.}
\end{argmini}
```

outputs:

$$\begin{aligned} w^* = \quad & \arg \min_w \quad f(w) + R(w + 6x) + \nabla_w R \\ & \text{subject to} \quad \begin{aligned} g(w) &= 0, \\ n(w) &= 6, \\ L(w) + r(x) &= Kw + p, \\ h(x) &= 0. \end{aligned} \end{aligned} \quad (7)$$

5 The *maxi* and *argmaxi* environments

Exactly the same syntax and definition as the previous environments, but now for defining maximization environments. The following code serves for illustration:

```

\begin{maxi}{4}
  {w}{f(w)+ R(w+6x) + \nabla_w R}
  {g(w)}{=0}

  {\label{eq:Example1}}{}

  \addConstraint{n(w)}{= 6}
  \addConstraint{L(w)+r(x)}{=Kw+p}
  \finalConstraint{h(x)}{=0.}
\end{maxi}

```

outputs:

$$\begin{aligned}
& \underset{w}{\text{maximize}} && f(w) + R(w + 6x) + \nabla_w R \\
& \text{subject to} && g(w) = 0, \\
& && n(w) = 6, \\
& && L(w) + r(x) = Kw + p, \\
& && h(x) = 0.
\end{aligned} \tag{8}$$

6 Problems and limitations

One current limitation is that the size of the optimization variables must be smaller than the word minimize, otherwise, the output is not properly aligned. Example:

$$\underset{x_0, u_0, x_1, \dots, u_{N-1}, x_N}{\text{minimize}} \quad \sum_{k=0}^{N-1} L(x_k, u_k) + E(x_N) \tag{9a}$$

$$\text{subject to} \quad x_{k+1} - f(x_k, u_k) = 0, \quad k = 0, \dots, N-1, \tag{9b}$$

$$h(x_k, u_k) \leq 0, \quad k = 0, \dots, N-1, \tag{9c}$$

$$r(x_0, x_N) = 0. \tag{9d}$$

A possible way to avoid this is to stack them with the command:

```

\substack{x_0, u_0, x_1, \hdots, \u_{N-1}, x_N}

```

$$\underset{\substack{x_0, u_0, x_1, \dots, \\ u_{N-1}, x_N}}{\text{minimize}} \quad \sum_{k=0}^{N-1} L(x_k, u_k) + E(x_N) \tag{10a}$$

$$\text{subject to} \quad x_{k+1} - f(x_k, u_k) = 0, \quad k = 0, \dots, N-1, \tag{10b}$$

$$h(x_k, u_k) \leq 0, \quad k = 0, \dots, N-1, \tag{10c}$$

$$r(x_0, x_N) = 0. \tag{10d}$$

If you want to increase the size of the optimization variables: A possible way to avoid this is to stack them with the command:

`\substack{\displaystyle x_0,u_0,x_1,\hdots,\displaystyle u_{N-1},x_N}`

$$\begin{array}{l} \text{minimize} \\ x_0, u_0, x_1, \dots, \\ u_{N-1}, x_N \end{array} \quad \sum_{k=0}^{N-1} L(x_k, u_k) + E(x_N) \quad (11a)$$

$$\text{subject to} \quad x_{k+1} - f(x_k, u_k) = 0, \quad k = 0, \dots, N-1, \quad (11b)$$

$$h(x_k, u_k) \leq 0, \quad k = 0, \dots, N-1, \quad (11c)$$

$$r(x_0, x_N) = 0. \quad (11d)$$

The other option is to define the set of variables before the problem definition as a single variable, i.e. $w = [x_0, u_0, x_1, \dots, u_{N-1}, x_N]$ and:

7 Code definition

```
%% optidef.sty
%% Copyright 2016 J. Lago Garcia
%
% This work may be distributed and/or modified under the
% conditions of the LaTeX Project Public License, either version 1.3
% of this license or (at your option) any later version.
% The latest version of this license is in
%   http://www.latex-project.org/lppl.txt
% and version 1.3 or later is part of all distributions of LaTeX
% version 2005/12/01 or later.
%
% This work has the LPPL maintenance status ‘maintained’.
%
% The Current Maintainer of this work is J. Lago Garcia, under the supervision
% of Prof. Dr. Moritz Diehl and Prof. Dr. Sebastien Gross
%
% This work consists of the file optidef.sty.

\NeedsTeXFormat{LaTeX2e}
\ProvidesPackage{optidef}[2016/06/06 Package for defining optimization problems]

\RequirePackage{environ}
\RequirePackage{ifthen}
\RequirePackage{mathtools}
\RequirePackage{xifthen}

% Input minimization environments
```

```

% Macros for objective definition, constraint definition and extra constraint definition
\newcommand{\bodyobj}[4]
{
\ifthenelse{\isempty{#4}}
{
&\underset{\displaystyle #1}{\mbox{#3}} \quad #2\span\span\span\span
}
{
#4 ~~ &\underset{\displaystyle #1}{\mbox{#3}} \quad #2\span\span\span\span
}
}

\newcommand{\bodyconst}[2]
{\&\mbox{subject to} \quad \&#1 & #2\span\span}

\newcommand{\addConstraint}[2]{\&\quad \&#1 & #2, \\\}
\newcommand{\finalConstraint}[2]{\&\quad \&#1 & #2}

%\newcommand{\breakObjectiveUnconstraint}[1]{\\%
%\bodyobjUn{#1}{\phantom{minimize}}{}}
\newcommand{\breakObjectiveOneConstraint}[1]{\&\&#1\\}
%\newcommand{\breakObjective}[1]{\bodyobj{#4}{\phantom{minimize}}{\nonumber\\}
}

\newcommand{\bodyconstOne}[2]
{\&\text{subject to} \quad \&\&#1 #2}

% This body of the objective is only valid for
% one constraint problem since there is no need to
% use mathllap to achieve second alignment level
\newcommand{\bodyobjOne}[4]
{
\ifthenelse{\isempty{#4}}
{
&\underset{\displaystyle #1}{\text{#3}} \quad \&\&#2
}
{
#4 ~~ &\underset{\displaystyle #1}{\text{#3}} \quad \&\&#2
}
}

% This body of the objective is only valid for
% no constraint problem since there is no need to

```

```

% align
\newcommand{\bodyobjUn}[4]
{
\ifthenelse{\isempty{#4}}
{
}
{
#4~
}
\underset{\displaystyle #1}{\text{#3}} \quad #2
}

%MINIMIZATION ENVIRONMENTS

\NewEnviron{mini}[7]{%
\ifthenelse{\equal{#1}{0}}{%
\begin{equation}
#6
\bodyobjUn{#2}{#3}{minimize}{#7}
\end{equation}
}%
{%
\ifthenelse{\equal{#1}{1}}{%
\begin{equation}
#6
\begin{alignedat}{3}
\bodyobjOne{#2}{#3}{minimize}{#7}\\
\bodyconstOne{#4}{#5}
\end{alignedat}
\end{equation}
}%
{%
\begin{equation}
#6
\begin{alignedat}{4}
\bodyobj{#2}{#3}{minimize}{#7}\\
\bodyconst{#4}{#5}, \\
\BODY
\end{alignedat}
\end{equation}
}%
}%
}

\NewEnviron{argmini}[7]{%
\ifthenelse{\equal{#1}{0}}{%

```

```

\begin{equation}
#6
\bodyobjUn{#2}{#3}{arg min}{#7}
\end{equation}
}%
{%
\ifthenelse{\equal{#1}{1}}{%
\begin{equation}
#6
\begin{alignedat}{3}
\bodyobjOne{#2}{#3}{arg min}{#7}\\
\bodyconstOne{#4}{#5}
\end{alignedat}
\end{equation}
}%
{%
\begin{equation}
#6
\begin{alignedat}{4}
\bodyobj{#2}{#3}{arg min}{#7}\\
\bodyconst{#4}{#5,} \\
\BODY
\end{alignedat}
\end{equation}
}%
}%
}

\NewEnviron{mini*}[7]{%
\ifthenelse{\equal{#1}{0}}{%
\begin{equation*}
\bodyobjUn{#2}{#3}{minimize}{#7}
\end{equation*}
}%
{%
\ifthenelse{\equal{#1}{1}}{%
\begin{alignat*}{3}
\bodyobjOne{#2}{#3}{minimize}{#7}\\
\bodyconstOne{#4}{#5}
\end{alignat*}
}%
{%
\begin{alignat*}{5}
\bodyobj{#2}{#3}{minimize}{#7}\\
\bodyconst{#4}{#5,} \\
\BODY

```

```

\end{alignat*}
}%
}%
}

\NewEnviron{argmini*}[7]{%
\ifthenelse{\equal{#1}{0}}{%
\begin{equation*}
\bodyobjUn{#2}{#3}{arg min}{#7}
\end{equation*}
}%
{%
\ifthenelse{\equal{#1}{1}}{%
\begin{alignat*}{3}
\bodyobjOne{#2}{#3}{arg min}{#7}\\
\bodyconstOne{#4}{#5}
\end{alignat*}
}%
{%
\begin{alignat*}{4}
\bodyobj{#2}{#3}{arg min}{#7}\\
\bodyconst{#4}{#5,} \\
\BODY
\end{alignat*}
}%
}%
}

```

```

\NewEnviron{mini!}[7]{%
\ifthenelse{\equal{#1}{1}}{%
\begin{subequations}
#6
\begin{alignat}{3}
\bodyobjOne{#2}{#3}{minimize}{#7}\\
\bodyconstOne{#4}{#5}
\end{alignat}
\end{subequations}
}%
{%
\begin{subequations}
#6
\begin{alignat}{4}
\bodyobj{#2}{#3}{minimize}{#7}\\
\bodyconst{#4}{#5,} \\
\BODY

```

```

\end{alignat}
\end{subequations}
}%
}

\NewEnviron{argmini!}[7]{%
\ifthenelse{\equal{#1}{1}}{%
\begin{subequations}
#6
\begin{alignat}{3}
\bodyobjOne{#2}{#3}{arg min}{#7}\\
\bodyconstOne{#4}{#5}
\end{alignat}
\end{subequations}
}%
{%
\begin{subequations}
#6
\begin{alignat}{4}
\bodyobj{#2}{#3}{arg min}{#7}\\
\bodyconst{#4}{#5}, \\
\BODY
\end{alignat}
\end{subequations}
}%
}

```

%MAXIMIZATION ENVIRONMENTS

```

\NewEnviron{maxi}[7]{%
\ifthenelse{\equal{#1}{0}}{%
\begin{equation}
#6
\bodyobjUn{#2}{#3}{maximize}{#7}
\end{equation}
}%
{%
\ifthenelse{\equal{#1}{1}}{%
\begin{equation}
#6
\begin{alignedat}{3}
\bodyobjOne{#2}{#3}{maximize}{#7}\\
\bodyconstOne{#4}{#5}
\end{alignedat}
\end{equation}
}%
}

```

```

{%
\begin{equation}
#6
\begin{alignedat}{4}
\bodyobj{#2}{#3}{maximize}{#7}\\
\bodyconst{#4}{#5,} \\
\BODY
\end{alignedat}
\end{equation}
}%
}%
}

\NewEnviron{argmaxi}[7]{%
\ifthenelse{\equal{#1}{0}}{%
\begin{equation}
#6
\bodyobjUn{#2}{#3}{arg max}{#7}
\end{equation}
}%
{%
\ifthenelse{\equal{#1}{1}}{%
\begin{equation}
#6
\begin{alignedat}{3}
\bodyobjOne{#2}{#3}{arg max}{#7}\\
\bodyconstOne{#4}{#5}
\end{alignedat}
\end{equation}
}%
{%
\begin{equation}
#6
\begin{alignedat}{4}
\bodyobj{#2}{#3}{arg max}{#7}\\
\bodyconst{#4}{#5,} \\
\BODY
\end{alignedat}
\end{equation}
}%
}%
}

\NewEnviron{maxi*}[7]{%
\ifthenelse{\equal{#1}{0}}{%
\begin{equation*}

```

```

\bodyobjUn{#2}{#3}{maximize}{#7}
\end{equation*}
}%
{%
\ifthenelse{\equal{#1}{1}}{%
\begin{alignat*}{3}
\bodyobjOne{#2}{#3}{maximize}{#7}\\
\bodyconstOne{#4}{#5}
\end{alignat*}
}%
{%
\begin{alignat*}{5}
\bodyobj{#2}{#3}{maximize}{#7}\\
\bodyconst{#4}{#5}, \\
\BODY
\end{alignat*}
}%
}%
}

```

```

\NewEnviron{argmaxi*}[7]{%
\ifthenelse{\equal{#1}{0}}{%
\begin{equation*}
\bodyobjUn{#2}{#3}{arg max}{#7}
\end{equation*}
}%
{%
\ifthenelse{\equal{#1}{1}}{%
\begin{alignat*}{3}
\bodyobjOne{#2}{#3}{arg max}{#7}\\
\bodyconstOne{#4}{#5}
\end{alignat*}
}%
{%
\begin{alignat*}{4}
\bodyobj{#2}{#3}{arg max}{#7}\\
\bodyconst{#4}{#5}, \\
\BODY
\end{alignat*}
}%
}%
}

```

```

\NewEnviron{maxi!}[7]{%
\ifthenelse{\equal{#1}{1}}{%

```



```

\begin{subequations}
#6
\begin{alignat}{3}
\bodyobjOne{#2}{#3}{maximize}{#7}\\
\bodyconstOne{#4}{#5}
\end{alignat}
\end{subequations}
}%
{%
\begin{subequations}
#6
\begin{alignat}{4}
\bodyobj{#2}{#3}{maximize}{#7}\\
\bodyconst{#4}{#5,} \\
\BODY
\end{alignat}
\end{subequations}
}%
}

\NewEnviron{argmaxi!}[7]{%
\ifthenelse{\equal{#1}{1}}{%
\begin{subequations}
#6
\begin{alignat}{3}
\bodyobjOne{#2}{#3}{arg max}{#7}\\
\bodyconstOne{#4}{#5}
\end{alignat}
\end{subequations}
}%
{%
\begin{subequations}
#6
\begin{alignat}{4}
\bodyobj{#2}{#3}{arg max}{#7}\\
\bodyconst{#4}{#5,} \\
\BODY
\end{alignat}
\end{subequations}
}%
}

```