

Algorithms

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1 Introduction

This package provides two environments, `algorithmic` and `algorithm`, which are designed to be used together but may, depending on the necessities of the author, be used separately.

The `algorithmic` environment provides an environment for describing algorithms and the `algorithm` environment provides a “float” wrapper for algorithms (implemented using `algorithmic` or some other method at the author’s option). The reason that two environments are provided is to allow the author maximum flexibility.

This work may be distributed and/or modified under the conditions of the GNU Lesser General Public License as published by the Free Software Foundation (see the file `COPYING` included in this package). Currently, this package consists of three files: `algorithm.sty`, `algorithmic.sty` and `algorithms.tex` (the source of this document). This is likely to change in the near future.

2 The algorithmic Environment

Within an `algorithmic` a number of commands for typesetting popular algorithmic constructs are available. In general, the commands provided can be arbitrarily nested to describe quite complex algorithms. An optional argument to the `\begin{algorithmic}` statement can be used to turn on line numbering by giving a positive integer indicating the required frequency of line numbering. For example, `\begin{algorithmic}[5]` would cause every fifth line to be numbered.

2.1 The Simple Statement

The simple statement takes the form

```
\STATE <text>
```

and is used for simple statements, e.g.

```
\begin{algorithmic}
\STATE $$ \leftarrow 0$
\end{algorithmic}
```

would produce

$$S \leftarrow 0$$

and with line numbering selected for every line using

```
\begin{algorithmic}[1]
\STATE $$ \leftarrow 0$
\end{algorithmic}
```

would produce

1: $S \leftarrow 0$

For users of earlier versions of `algorithmic` this construct is a cause of an incompatibility. In the earlier version, instead of starting simple statements with the `\STATE` command, simple statements were entered as free text and terminated with `\\` command. Unfortunately, this simpler method failed to survive the modifications necessary for statement numbering. However, the `\\` command can still be used to force a line break within a simple statement.

2.2 The *if-then-else* Construct

The *if-then-else* construct takes the forms.

```
\IF{<condition>} <text> \ENDIF
\IF{<condition>} <text1> \ELSE <text2> \ENDIF
\IF{<condition1>} <text1> \ELSIF{<condition2>} <text2> \ELSE <text3> \ENDIF
```

In the third of these forms there is no limit placed on the number of `\ELSIF{<C>}` that may be used. For example,

```
\begin{algorithmic}
\IF{some condition is true}
\STATE do some processing
\ELSIF{some other condition is true}
\STATE do some different processing
\ELSIF{some even more bizarre condition is met}
\STATE do something else
\ELSE
\STATE do the default actions
\ENDIF
\end{algorithmic}
```

would produce

```
if some condition is true then
  do some processing
else if some other condition is true then
  do some different processing
else if some even more bizarre condition is met then
  do something else
else
  do the default actions
end if
```

with appropriate indentations.

2.3 The *for* Loop

The *for* loop takes the forms.

```
\FOR{<condition>} <text> \ENDFOR
\FORALL{<condition>} <text> \ENDFOR
```

For example,

```
\begin{algorithmic}
\FOR{$i=0$ to $10$}
\STATE carry out some processing
\ENDFOR
\end{algorithmic}
```

produces

```
for  $i = 0$  to 10 do
    carry out some processing
end for
```

and

```
\begin{algorithmic}[1]
\FORALL{$i$ such that  $0 \leq i \leq 10$ }
\STATE carry out some processing
\ENDFOR
\end{algorithmic}
```

produces

```
1: for all  $i$  such that  $0 \leq i \leq 10$  do
2:   carry out some processing
3: end for
```

2.4 The *while* Loop

The *while* loop takes the form.

```
\WHILE{<condition>} <text> \ENDWHILE
```

For example,

```
\begin{algorithmic}
\WHILE{some condition holds}
\STATE carry out some processing
\ENDWHILE
\end{algorithmic}
```

produces

```
while some condition holds do
    carry out some processing
end while
```

2.5 The *repeat-until* Loop

The *repeat-until* loop takes the form.

```
\REPEAT <text> \UNTIL{<condition>}
```

For example,

```
\begin{algorithmic}
\REPEAT
\STATE carry out some processing
\UNTIL{some condition is met}
\end{algorithmic}
```

produces

```
repeat
    carry out some processing
until some condition is met
```

2.6 The Infinite Loop

The infinite loop takes the form.

```
\LOOP <text> \ENDLOOP
```

For example,

```
\begin{algorithmic}
\LOOP
\STATE this processing will be repeated forever
\ENDLOOP
\end{algorithmic}
```

produces

```
loop
    this processing will be repeated forever
end loop
```

2.7 The Precondition

The precondition (that must be met if an algorithm is to correctly execute) takes the form:

```
\REQUIRE <text>
```

For example,

```
\begin{algorithmic}
\REQUIRE  $x \neq 0$  and  $n \geq 0$ 
\end{algorithmic}
```

produces

Require: $x \neq 0$ and $n \geq 0$

2.8 The Postcondition

The postcondition (that must be met after an algorithm has correctly executed) takes the form:

```
\ENSURE <text>
```

For example,

```
\begin{algorithmic}
\ENSURE  $x \neq 0$  and  $n \geq 0$ 
\end{algorithmic}
```

produces

Ensure: $x \neq 0$ and $n \geq 0$

2.9 Returning Values

The `algorithmic` environment offers a special statement for explicitly returning values in algorithms. It has the syntax:

```
\RETURN <text>
```

For example,

```
\begin{algorithmic}
\RETURN  $(x+y)/2$ 
\end{algorithmic}
```

produces

return $(x + y)/2$

2.10 Printing Messages

Another feature of the `algorithmic` environment is that it currently provides a standard way of printing values (which is an operation used enough to merit its own keyword). It has the syntax:

```
\PRINT <text>
```

For example,

```
\begin{algorithmic}
\PRINT \texttt{‘‘Hello, World!’’}
\end{algorithmic}
```

produces

print `‘‘Hello, World!’’`

2.11 Comments

Comments may be inserted at most points in an algorithm using the form:

```
\COMMENT{<text>}
```

For example,

```
\begin{algorithmic}
\STATE do something \COMMENT{this is a comment}
\end{algorithmic}
```

produces

```
do something {this is a comment}
```

Because the mechanisms used to build the various algorithmic structures make it difficult to use the above mechanism for placing comments at the end of the first line of a construct, the commands `\IF`, `\ELSIF`, `\ELSE`, `\WHILE`, `\FOR`, `\FORALL`, `\REPEAT` and `\LOOP` all take an optional argument which will be treated as a comment to be placed at the end of the line on which they appear. For example,

```
repeat {this is comment number one}
  if condition one is met then {this is comment number two}
    do something
  else if condition two is met then {this is comment number three}
    do something else
  else {this is comment number four}
    do nothing
  end if
until hell freezes over
```

2.12 An Example

The following example demonstrates the use of the `algorithmic` environment to describe a complete algorithm. The following input

```
\begin{algorithmic}
\REQUIRE $n \geq 0$
\ENSURE $y = x^n$
\STATE $y \leftarrow 1$
\STATE $X \leftarrow x$
\STATE $N \leftarrow n$
\WHILE{$N \neq 0$}
\IF{$N$ is even}
\STATE $X \leftarrow X \times X$
\STATE $N \leftarrow N / 2$
\ELSE[$N$ is odd]
\STATE $y \leftarrow y \times X$
\STATE $N \leftarrow N - 1$
\ENDIF
\ENDWHILE
\END
```

```

\ENDIF
\ENDWHILE
\end{algorithmic}

```

will produce

Require: $n \geq 0$

Ensure: $y = x^n$

```

 $y \leftarrow 1$ 
 $X \leftarrow x$ 
 $N \leftarrow n$ 
while  $N \neq 0$  do
  if  $N$  is even then
     $X \leftarrow X \times X$ 
     $N \leftarrow N/2$ 
  else  $\{N$  is odd $\}$ 
     $y \leftarrow y \times X$ 
     $N \leftarrow N - 1$ 
  end if
end while

```

which is an algorithm for finding the value of a number taken to a non-negative power.

2.13 Options and Customization

There is a single option, `noend` that may be invoked when the `algorithmic` package is loaded. With this option invoked the *end* statements are omitted in the output. This allows space to be saved in the output document when this is an issue.

2.13.1 Changing Indentation

In the spirit of saving vertical space (which is especially important when submitting a paper for a journal, where space is frequently limited for authors), the `algorithmic` environment offers, beginning with the version released in 2005-05-08, a way to control the amount of indentation that is used by a given algorithm.

The amount of indentation to be used is given by the command

```
\algsetup{indent=length}
```

where *length* is any valid length used by `TeX`. The default value of the indentation used by the `algorithmic` environment is 1 em (for “backward compatibility reasons”), but a value of 2 em or more is recommended, depending on the publication. For example, the snippet

```

\algsetup{indent=2em}
\begin{algorithmic}[1]

```



```

\STATE $a \Leftarrow 1$
\IF{$a$ is even}
\PRINT ‘‘$a$ is even’’
\ELSE
\PRINT ‘‘$a$ is odd’’
\end{algorithmic}

```

produces

```

1:  $a \Leftarrow 1$ 
2: if  $a$  is even then
3:   print “ $a$  is even”
4: else
5:   print “ $a$  is odd”
6: end if

```

while

```

\algsetup{indent=5em}
\begin{algorithmic}[1]
\STATE $a \Leftarrow 1$
\IF{$a$ is even}
\PRINT ‘‘$a$ is even’’
\ELSE
\PRINT ‘‘$a$ is odd’’
\end{algorithmic}

```

would produce

```

1:  $a \Leftarrow 1$ 
2: if  $a$  is even then
3:   print “ $a$  is even”
4: else
5:   print “ $a$  is odd”
6: end if

```

The intended use of this option is to allow the author to omit the *end* (see Section 2.13 for details) statements without losing readability, by increasing the amount of indentation to a suitable level.

2.13.2 Changing Line Numbering

As mentioned in Section 2 and illustrated in Section 2.13.1, `algorithms` already provides you with the possibility of numbering lines.

Starting with the version released in 2005-07-05, you can now change two aspects of line numbering: the size of the line numbers (which, by default, is `\footnotesize`) and the delimiter used to separate the line number from the code (which, by default, is `:`, i.e., a colon).

You can change the size of the line numbers using the command:

```

\algsetup{linenosize=size}

```

where *size* is any of the various commands provided by L^AT_EX to change the size of the font to be used. Among others, useful values are `\tiny`, `\scriptsize`, `\footnotesize` and `\small`. Please see the complete list of sizes in your L^AT_EX documentation.

As another frequently requested feature, you can change the delimiter used with the line numbers by issuing the command:

```
\algsetup{linenodelimiter=delimiter}
```

where *delimiter* is any “well-formed” string, including the empty string. With this command, you can change the colon to a period (.) by issuing the command

```
\algsetup{linenodelimiter=.}
```

or even omit the delimiter, by specifying the empty string or a space (`\`), whatever seems best for your document.

As an example of such commands, the code produced by

```
\algsetup{linenosize=\small,
          linenodelimiter=.}
\begin{algorithmic}[1]
  \STATE  $i \leftarrow 10$ 
  \RETURN  $i$ 
\end{algorithmic}
```

would be something like

1. $i \leftarrow 10$
2. **return** i

2.13.3 Customization

In order to facilitate the use of this package with foreign languages, all of the words in the output are produced via redefinable macro commands. The default definitions of these macros are:

```
\newcommand{\algorithmicrequire}{\textbf{Require:}}
\newcommand{\algorithmicensure}{\textbf{Ensure:}}
\newcommand{\algorithmicend}{\textbf{end}}
\newcommand{\algorithmicif}{\textbf{if}}
\newcommand{\algorithmicthen}{\textbf{then}}
\newcommand{\algorithmicelse}{\textbf{else}}
\newcommand{\algorithmicelsif}{\algorithmicelse\ \algorithmicif}
\newcommand{\algorithmicendif}{\algorithmicend\ \algorithmicif}
\newcommand{\algorithmicfor}{\textbf{for}}
\newcommand{\algorithmicforall}{\textbf{for all}}
\newcommand{\algorithmicdo}{\textbf{do}}
\newcommand{\algorithmicendfor}{\algorithmicend\ \algorithmicfor}
\newcommand{\algorithmicwhile}{\textbf{while}}
```

```

\newcommand{\algorithmicendwhile}{\algorithmicend\ \algorithmicwhile}
\newcommand{\algorithmicloop}{\textbf{loop}}
\newcommand{\algorithmicendloop}{\algorithmicend\ \algorithmicloop}
\newcommand{\algorithmicrepeat}{\textbf{repeat}}
\newcommand{\algorithmicuntil}{\textbf{until}}
\newcommand{\algorithmicprint}{\textbf{print}}
\newcommand{\algorithmicreturn}{\textbf{return}}

```

In addition, the formatting of comments is implemented via a single argument command macro which may also be redefined. The default definition is

```

\newcommand{\algorithmiccomment}[1]{\{#1\}}

```

and another option that may be interesting for users familiar with C-like languages is to redefine the comments to be

```

\renewcommand{\algorithmiccomment}[1]{//#1}

```

Comments produced this way would be like this:

```

 $i \leftarrow i + 1$  //Increments  $i$ 

```

This second way to present comments may become the default in a future version of the package.

3 The algorithm Environment

3.1 General

When placed within the text without being encapsulated in a floating environment `algorithmic` environments may be split over a page boundary greatly detracting from their appearance. In addition, it is useful to have algorithms numbered for reference and for lists of algorithms to be appended to the list of contents. The `algorithm` environment is meant to address these concerns by providing a floating environment for algorithms. For example, the input text

```

\begin{algorithm}
\caption{Calculate  $y = x^n$ }
\label{alg1}
\begin{algorithmic}
\REQUIRE  $n \geq 0$  \vee  $x \neq 0$ 
\ENSURE  $y = x^n$ 
\STATE  $y \leftarrow 1$ 
\IF{ $n < 0$ }
\STATE  $X \leftarrow 1 / x$ 
\STATE  $N \leftarrow -n$ 
\ELSE
\STATE  $X \leftarrow x$ 
\STATE  $N \leftarrow n$ 

```

Algorithm 1 Calculate $y = x^n$

Require: $n \geq 0 \vee x \neq 0$ **Ensure:** $y = x^n$

```

 $y \leftarrow 1$ 
if  $n < 0$  then
   $X \leftarrow 1/x$ 
   $N \leftarrow -n$ 
else
   $X \leftarrow x$ 
   $N \leftarrow n$ 
end if
while  $N \neq 0$  do
  if  $N$  is even then
     $X \leftarrow X \times X$ 
     $N \leftarrow N/2$ 
  else  $N$  is odd
     $y \leftarrow y \times X$ 
     $N \leftarrow N - 1$ 
  end if
end while
```

```

\ENDIF
\WHILE{ $\$N \neq 0$ }
\IF{ $\$N$  is even}
\STATE  $\$X \leftarrow X \times X$ 
\STATE  $\$N \leftarrow N / 2$ 
\ELSE[ $\$N$  is odd]
\STATE  $\$y \leftarrow y \times X$ 
\STATE  $\$N \leftarrow N - 1$ 
\ENDIF
\ENDWHILE
\end{algorithmic}
\end{algorithm}
```

produces Algorithm 1 which is a slightly modified version of the earlier algorithm for determining the value of a number taken to an integer power. In this case, provided the power may be negative provided the number is not zero.

The command `\listofalgorithms` may be used to produce a list of algorithms as part of the table contents as shown at the beginning of this document. An auxiliary file with a suffix of `.loa` is produced when this feature is used.

3.2 Options

The appearance of the typeset algorithm may be changed by use of the options: `plain`, `boxed` or `ruled` during the loading of the `algorithm` package. The

default option is **ruled**.

The numbering of algorithms can be influenced by providing the name of the document component within which numbering should be recommenced. The legal values for this option are: **part**, **chapter**, **section**, **subsection**, **subsubsection** or **nothing**. The default value is **nothing** which causes algorithms to be numbered sequentially throughout the document.

3.3 Customization

In order to facilitate the use of this package with foreign languages, methods have been provided to facilitate the necessary modifications.

The title used in the caption within **algorithm** environment can be set by use of the standard **\floatname** command which is provided as part of the **float** package which was used to implement this package. For example,

```
\floatname{algorithm}{Procedure}
```

would cause **Procedure** to be used instead of **Algorithm** within the caption of algorithms.

In a manner analogous to that available for the built in floating environments, the heading used for the list of algorithms may be changed by redefining the command **listalgorithmname**. The default definition for this command is

```
\newcommand{\listalgorithmname}{List of Algorithms}
```

4 Labels and References in Algorithms

With the release of 2005-07-05, now **algorithmic** accepts labels and references to specific lines of a given algorithm, so you don't have to hardcode the line numbers yourself when trying to explain what the code does in your texts. Thanks to Arnaud Legrand for the suggestion and patch for this highly missed feature.

An example of its use is shown in Algorithm 2. See that, in line 10, we deal with the case of N being even, while, in line 13, we give treatment to the case of N being odd.

Algorithm 2 Calculate $y = x^n$

Require: $n \geq 0 \vee x \neq 0$

Ensure: $y = x^n$

```
1:  $y \leftarrow 1$ 
2: if  $n < 0$  then
3:    $X \leftarrow 1/x$ 
4:    $N \leftarrow -n$ 
5: else
6:    $X \leftarrow x$ 
7:    $N \leftarrow n$ 
8: end if
9: while  $N \neq 0$  do
10:  if  $N$  is even then
11:     $X \leftarrow X \times X$ 
12:     $N \leftarrow N/2$ 
13:  else
14:     $y \leftarrow y \times X$ 
15:     $N \leftarrow N - 1$ 
16:  end if
17: end while
```
