eolang: LaTeX Package for Formulas and Graphs of EO Programming Language and φ-calculus*

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NB! You must run TeX processor with `--shell-escape` option and you must have Perl installed. This package doesn't work on Windows.

1 Introduction

This package helps you print formulas of φ-calculus, which is a formal foundation of EO programming language. The calculus was introduced by Bugayenko (2021) and later formalized by Kudasov et al. (2022). Here is how you render a simple expression:

$$\texttt{app} \mapsto [\![\\ \quad \rho \mapsto \xi.b.^{2}, \alpha_0 | t \rightsquigarrow \texttt{TRUE}, \\ \quad b \mapsto [\![\alpha_* \mapsto \texttt{fn}(56), \\ \quad\quad \varphi \mapsto \Phi.\texttt{hello.bye}(\xi), \\ \quad\quad \Delta \mapsto \texttt{01-FE-C3}]\!], \\ x \mapsto [\![\lambda \mapsto \varnothing]\!].$$

```
\documentclass{minimal}
\usepackage{eolang}
\begin{document}
\begin{phiquation*}
app -> [[ % it's abstract!
  ^ !-> $.b.^{^2}, 0/t~> TRUE,
  b -> [[ *-> fn(56),
    @ -> Q.hello.bye($),
    D> 01-FE-C3 ]]]],\\
x -> [[ \lambda ..> ? ]].
\end{phiquation*}
\end{document}
```

`phiquation` (*env.*) The environment `phiquation` lets you write a φ-calculus expressions using simple plain-text notation, where:

*The sources are in GitHub at objectionary/eolang.sty

- “@” maps to “φ” (\varphi),
- “^” maps to “ρ” (\rho),
- “$” maps to “$\xi$” (\xi),
- “&” maps to “σ” (\sigma),
- “?” maps to “$\varnothing$” (\varnothing),
- “Q” maps to “Φ” (\Phi),
- “->” maps to “$\mapsto$” (\mapsto),
- “~>” maps to “$\rightsquigarrow$” (\phiWave),
- “!->” maps to “$\mapsto\!\!\!|$” (\phiConst),
- “..>” maps to “$\dashrightarrow$” (\phiDotted),
- “D>” maps to “$\Delta \dashrightarrow$” (\Delta ..>),
- “L>” maps to “$\lambda \dashrightarrow$” (\lambda ..>),
- “[[” maps to “$[\![$” (\llbracket),
- “]]” maps to “$]\!]$” (\rrbracket),
- “==” maps to “$\equiv$” (\equiv),
- “|abc|” maps to “abc” (\texttt{abc}).

Also, a few symbols are supported for φPU architecture:

- “<<” maps to “$\langle$” (\langle),
- “>>” maps to “$\rangle$” (\rangle),
- “-abc>” maps to “$\xrightarrow{\text{ABC}}$” (\phiSlot{abc}),
- “:=” maps to “$\vDash$” (\vDash).

Before any arrow you can put a number, which will be rendered as \alpha with an index, for example \phiq{0->x} will render “$\alpha_0 \mapsto x$”. Instead of a number you can use asterix too.

You can append a slash and a title to the number of an attribute, such as 0/g->x. this will render as $\alpha_0|g \mapsto x$. You can use fixed-width words too, for example \phiq{0/|f|->x} will render as “$\alpha_0|\texttt{f} \mapsto x$”. It’s also possible to use an asterix instead of a number, such that \phiq{*/g->x} renders as “$\alpha_*|g \mapsto x$”

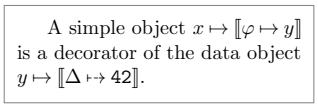
Numbers are automatically converted to fixed-width font, no need to always decorate them with vertical bars.

TRUE and FALSE are automatically converted to fixed-width font too.

Object names are automatically converted to fixed-width font too, if they have more than one letter.

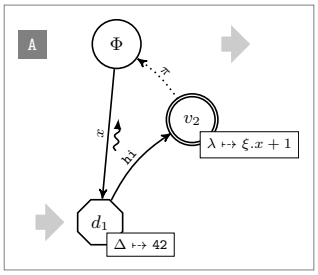
Texts in double quotes are automatically converted to fixed-width font too.

\phiq The command \phiq lets you inline a φ-calculus expressions using the same simple plain-text notation. You can use dollar sign directly too:




```
\begin{document}
A simple object
\phiq{x -> [[@ -> y]]} \\
is a decorator of
the data object \\
$y -> [[\Delta ..> 42]]$.
\end{document}
```

`sodg` (*env.*) The environment `sodg` allows you to draw a SODG graph:




```
\documentclass{standalone}
\usepackage{eolang}
\begin{document}
\begin{sodg}
v0 \\ v0===> \\ v0!!A
v1 xy:v0,-.8,2.8 data:42 tag:d_1
v0->v1 a:x rho \\ =>v1
v2 xy:v0,+1,+1 atom:\xi.x+1
v1->v2 a:|hi| bend:-15
v2->v0 pi bend:10 % a comment
\end{sodg}
\end{document}
```

The content of the environment is parsed line by line. Markers in each line are separated by a single space. The first marker is either a unique name of a vertex, like "`v1`" in the example above, or an edge, like "`v0->v1`." All other markers are either unary like "`rho`" or binary like "`atom:$\xi.x+1$`." Binary markers have two parts, separated by colon.

The following markers are supported for a vertex:

- "`tag:<math>`" puts a custom label `<math>` into the circle,
- "`data:[<box>]`" makes it a data vertex with an optional attached "`<box>`" (the content of the box may only be numeric data),
- "`atom:[<box>]`" makes it an atom with an optional attached "`<box>`" (the content of the box is a math formula),
- "`box:<txt>`" attaches a "`<box>`" to it,
- "`xy:<v>,<r>,<d>`" places this vertex in a position relative to the vertex "`<v>`," shifting it right by "`<r>`" and down by "`<d>`" centimetres.
- "`+:<v>`" makes a copy of an existing vertex and all its kids.

The following markers are supported for an edge:

- "`rho`" places a backward snake arrow to the edge,
- "`bend:<angle>`" bend it right by the amount of "`<angle>`,"
- "`a:<txt>`" attaches label "`<txt>`" to it,
- "`pi`" makes it dotted, with π label.

It is also possible to put transformation arrows to the graph, with the help of "`v0=>v1`" syntax. The arrow will be placed exactly between two vertices. You can also put an arrow

from a vertex to the right, saying for example "`v3=>`", of from the left to the vertes, by saying for example "`=>v5`." If you want the arrow to stay further away from the vertex than usually, use a few "`=`" symbols, for example "`===>v0`."

You can also put a marker at the left side of a vertex, using "`v5!A`" syntax, where "`v5`" is the vertex and "`A`" is the text in the marker. They are useful when you put a few graphs on a picture explaining how one graph is transformed to another one and so forth. You can make a distance between the vertex and the marker a bit larger by using a few exclamation marks, for example "`v5!!!A`" will make a distance three times bigger.

You can make a clone of an existing vertex together with all its dependants, by using this syntax: "`v0+a`." Here, we make a copy of "`v0`" and call it "`v0a`." See the example below.

Be aware, unrecognized markers are simply ignored, without any error reporting.

`\eolang` `\phic` `\xmir` There is also a no-argument command `\eolang` to help you print the name of EO language. It understands the `anonymous` package option and prints itself differently, to double-blind your paper. There is also `\phic` command to print the name of φ-calculus, also sensitive to `anonymous` mode. The macro `\xmir` prints "XMIR".

In our research we use XYZ, an experimental object-oriented dataflow language, α-calculus, as its formal foundation, and XML$^+$ — its XML-based presentation.

```
\usepackage[anonymous]{eolang}
\begin{document}
In our research we use \eolang{}, \\
an experimental object-oriented \\
dataflow language, \phic{}, as its \\
formal foundation, and \xmir{} --- \\
its XML-based presentation.
\end{document}
```

Without the `anonymous` option there will be no orange color:

In our research we use EO, an experimental object-oriented dataflow language, φ-calculus, as its formal foundation, and XMIR — its XML-based presentation.

```
\usepackage{eolang}
\begin{document}
In our research we use \eolang{}, \\
an experimental object-oriented \\
dataflow language, \phic{}, as its \\
formal foundation, and \xmir{} --- \\
its XML-based presentation.
\end{document}
```

`\phiConst` `\phiWave` `\phiDotted` A few simple commands are defined to help you render arrows. It is recommended not to use them directly, but use `!->` instead. However, if you want to use `\phiConst`, wrap it in `\mathrel` for better display:

If x is an identifier and y is an object, then $x \mapsto y$ makes y a constant, $x \rightsquigarrow y$ makes it a decoratee of an arbitrary number of objects, while $x \mapsto y$ makes it a special attribute.

```
If $x$ is an identifier and $y$ is
an object, then $x \phiConst y$
makes $y$ a constant,
$x \phiWave y$ makes it a decoratee
of an arbitrary number of objects,
while $x \phiDotted y$ makes it
a special attribute.
```

`\phiOset` `\phiUset` If you want to put a text over an arrow or under it, use `\phiOset` and `\phiUset` respectively:

When the names of attributes and their values don't matter, we use an arrow with a star, for example:

$$[\![\overset{*}{\mapsto}]\!].$$

```
When the names of attributes and their
values don't matter, we use an arrow
with a star, for example:
\begin{phiquation*}
[[ \phiOset{*}{->} ]].
\end{phiquation*}
```

`\phiMany` Sometimes you may need to simplify the way you describe an object (the typesetting is a bit off, but this is not because of us, but because of this):

The expression $[\![\alpha_1 \mapsto x_1, \alpha_2 \mapsto x_2, \ldots, \alpha_n \mapsto x_n]\!]$ and expression $[\![\alpha_i \overset{n}{\underset{i=1}{\mapsto}} x_i]\!]$ are syntactically different but semantically equivalent.

```
The expression
\phiq{[[ 1-> x_1,
  2-> x_2, \dots,
  \alpha_n -> x_n ]]}
and expression
\phiq{[[ \alpha_i
  \phiMany{->}{i=1}{n} x_i ]]}
are syntactically different but
semantically equivalent.
```

`\phiSaveTo` `\sodgSaveTo` If you want to use `phiquation` or `sodg` environments inside `tabular` or any other environment or command, you won't be able to do this, because `phiquation` and `sodg` are "verbatim" environments. `\phiSaveTo` and `\sodgSaveTo` commands will help you in this situation. You use them right before `\begin{phiquation}` or `\begin{sodg}` respectively — the content of the equation or the graph won't be rendered, but instead saved to the file. Later, inside `tabular`, you can use it through the `\input` macro (don't forget the `\parbox`):

Free:	$[\![x \mapsto \varnothing]\!]$
Bound:	$[\![x \mapsto [\![\Delta \mapsto 42]\!]]\!]$

```
\phiSaveTo{a}
\begin{phiquation*}
[[ x -> [[D>42]] ]]
\end{phiquation*}
\begin{tabular}{p{.5in}l}
Free: & $[[x -> ?]]$ \\
Bound: & \parbox{1in}{\input{a}} \\
\end{tabular}
```

`\eoAnon` You may want to hide some of the content with the help of the `anonymous` package option. The command `\eoAnon` may help you with this. It has two parameters: one mandatory and one optional. The mandatory one is the content you want to show and the optional one is the substituion we will render if the `anonymous` package option is set.

2 Package Options

`tmpdir` The default location of temp files is `_eolang`. You can change this with the help of the `tmpdir` package option:

```
\usepackage[tmpdir=/tmp/foo]{eolang}
```

`nodollar` You may disable the special treatment of the dollar sign by using the `nodollar`

package option:

```
\usepackage[nodollar]{eolang}
```

anonymous

You may anonymize \eolang, \XMIR, and \phic commands by using anonymous package option (they all use the \eoAnon command mentioned earlier):

```
\usepackage[anonymous]{eolang}
```

3 More Examples

The phiquation environment treats ends of line as signals to start new lines in the formula. If you don't want this to happen and want to parse the next line as the a continuation of the current line, you can use a single backslash as it's done here:

$$\dfrac{x \mapsto ⟦\varphi \mapsto y⟧ \quad y \mapsto ⟦z \mapsto 42⟧}{x.z \mapsto 42}\text{R1}$$

```
\begin{phiquation*}
\dfrac \
 {x->[[@->y]] \quad y->[[z->42]]} \
 {x.z -> 42} \
 \text{\sffamily R1}
\end{phiquation*}
```

This is how you can use \dfrac from amsmath for large inference rules, with the help of \begin{split} and \end{split}:

$$\dfrac{\begin{split}x \mapsto ⟦\varphi \mapsto y, z \mapsto 42,\\ \alpha_0 | g \mapsto \varnothing, \alpha_1 | \texttt{foo} \mapsto 42⟧\end{split}}{\begin{split}x \mapsto ⟦\varphi \mapsto y, z \mapsto \varnothing, f \rightsquigarrow \texttt{pi}(\\ \alpha_0 \mapsto ⟦\psi \mapsto \texttt{hello}(12)⟧,\\ \alpha_1 \mapsto 42)⟧\end{split}}\text{R2}.$$

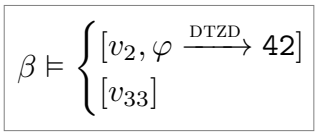
```
\begin{phiquation*}
\dfrac{\begin{split}
x->[[@->y, z->42,
  0/g->?, 1/foo->42]]
\end{split}}{\begin{split}
x->[[@->y, z->?, f ~> |pi|(
  0->[[ \psi !-> |hello|(12) ]],
    1->42)]]
\end{split}}\text{R2}.
\end{phiquation*}
```

You can use the matrix environment too, in order to group a few lines:

$$x \mapsto \left\{\begin{matrix} \varnothing \\ ⟦\lambda \mapsto \rho \times \xi.\alpha_0⟧ \\ ⟦\Delta \mapsto 42⟧ \end{matrix}\right\}$$

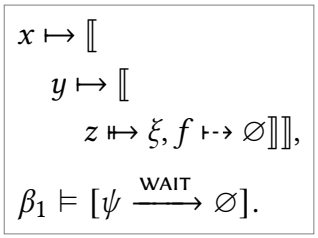
```
\begin{phiquation*}
x -> \left\{\begin{matrix} \
? \\
[[ L> ^ \times $.\alpha_0 ]] \\
[[ D> 42 ]] \
\end{matrix}\right\}
\end{phiquation*}
```

The cases environment works too:



```
\begin{phiquation*}
\beta := \begin{cases} \
[ v_2, @ -dtzd> 42 ] \\
[ v_{33} ] \
\end{cases}
\end{phiquation*}
\end{document}
```

The `phiquation` environment may be used together with the acmart package:



```
\documentclass{acmart}
\usepackage{eolang}
\thispagestyle{empty}
\begin{document}
\begin{phiquation*}
x -> [[
  y -> [[
    z !-> $, f ..> ? ]]]],\\
\beta_1 := [ \psi -wait> ? ].
\end{phiquation*}
\end{document}
```

It's possible to use `\label` inside the `phiquation` environment (pay attention to how you can disable our custom parsing of math formulas by means of curled brackets around the "4" number):

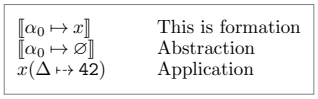
Discriminant can be calculated using the following simple formula:

$$D = b^2 - 4ac. \quad (1)$$

Eq. 1 is also widely used in number theory and polynomial factoring.

```
Discriminant can be calculated using
the following simple formula:
\begin{phiquation}
D = b{^2} - {4}ac.
\label{d}
\end{phiquation}
Eq.~\ref{d} is also widely used in
number theory and polynomial factoring.
```

You can add comments to your equations, using the `&&` command (pay attention, the text inside `\text{}` is not processed and treated like a plain text):



```
\begin{phiquation*}
[[ 0->x ]] && \text{This is formation}
[[ 0->? ]] && \text{Abstraction}
x(D>42) && \text{Application}
\end{phiquation*}
```

If you don't use `nodollar` package option, you can still use normal parsing of the dollar sign, by means of `\(...\)` syntax:

The object formation $[[\alpha_0 \mapsto x]]$ may be replaced with a formula $Q \times a^2$.

```
The object formation $[[0->x]]$
may be replaced with a formula
\( Q \times a^2 \).
```

The `phiquation` environment will automatically align formulas by the first arrow, if there are only left-aligned formulas:

$$
\begin{aligned}
x(\pi) &\mapsto [\![\lambda \mapsto f_1]\!],\\
x(a,b,c) &\mapsto [\![\alpha_0 \mapsto \varnothing, \varphi \mapsto \mathtt{hello}(\xi), x \mapsto \mathsf{FALSE}]\!],\\
\Delta &= \mathtt{43\text{-}09},\\
x(y) &\equiv x(\alpha_0 \mapsto y).
\end{aligned}
$$

```
\begin{phiquation*}
x(\pi) -> [[\lambda ..> f_1]], \\
x(a,b,c) -> [[ \alpha_0 -> ?, \
  @ -> |hello|($), x -> |FALSE| ]], \\
\Delta = |43-09|,
x(y) == x(0-> y).
\end{phiquation*}
```

If not a single line is indented in `phiquation`, all formulas will be centered:

$$
\begin{aligned}
[\![b \mapsto \varnothing]\!],\\
[\![\varphi \mapsto \mathsf{TRUE}, \Delta \mapsto 42]\!],\\
\psi = \langle \pi, 42 \rangle.
\end{aligned}
$$

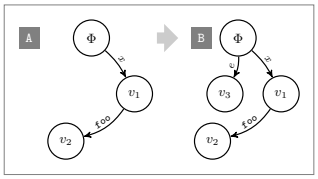
```
\begin{phiquation*}
[[ b -> ? ]],
[[ @ -> TRUE, \Delta ..> 42 ]], \\
\psi = << \pi, 42 >>.
\end{phiquation*}
```

It is possible to use “manual splitting” mode in the `phiquation` environment by starting the body with `\begin{split}`:

$$
\begin{aligned}
x(\pi) &\mapsto 4\\
x(a,b,c) &\mapsto [\![\alpha_0 \mapsto \varnothing]\!]
\end{aligned}
$$

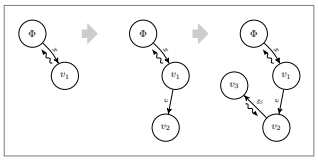
```
\begin{phiquation*}
\begin{split}
x(\pi) & -> 4 \\
x(a,b,c) & -> [[ \alpha_0 -> ? ]] \\
\end{split}
\end{phiquation*}
```

You can make a copy of a vertex together with its kids:



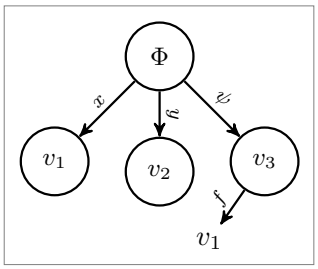

```
\begin{sodg}
v0 \\ v0!!A
v1 xy:v0,.7,1
v0->v1 a:x bend:-10
v2 xy:v1,-1.3,.8
v1->v2 a:|foo| bend:-20
v0+a xy:v0,3,0
v3a xy:v0a,-.7,1
v0a->v3a a:e bend:-15
v0=>v0a \\ v0a!B
\end{sodg}
```

You can make a copy from a copy:



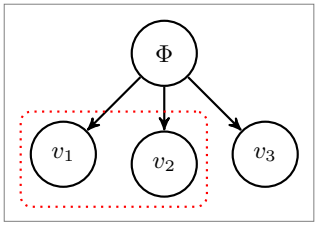
```
\begin{sodg}
v0
v1 xy:v0,.7,1
v0->v1 a:x bend:-10 rho
v0+a xy:v0,3,0 \\ v0=>v0a
v2a xy:v1a,-.8,1.3
v1a->v2a a:e
v0a+b xy:v0a,3,0 \\ v0a=>v0b
v3b xy:v2b,-1,-1
v2b->v3b a:\psi{} rho
\end{sodg}
```

You can have “broken” edges, using “`break`” attribute of an edge. The attribute must have a value, which is the percentange of the path between vertices that the arrow should take (can’t be more than 80 and less than 20). This may be convenient when you can’t fit all edges into the graph, for example:




```
\begin{sodg}
v0
v1 xy:v0,-1,1
v0->v1 a:x
v2 xy:v0,0,1
v0->v2 a:y
v3 xy:v0,1,1
v0->v3 a:\psi{}
v3->v1 a:f bend:-75 break:30
\end{sodg}
```

You can add TikZ commands to `sodg` graph, for example:




```
\begin{sodg}
v0
v1 xy:v0,-1,1 \\ v0->v1
v2 xy:v0,0,1 \\ v0->v2
v3 xy:v0,1,1 \\ v0->v3
\node[draw=red,rounded corners,\
 dotted,fit=(v1) (v2)] {};
\end{sodg}
```

4 Implementation

First, we include a few packages. We need stmaryrd for `\llbracket` and `\rrbracket` commands:

```
\RequirePackage{stmaryrd}
```

We need amsmath for `equation*` environment:

```
\RequirePackage{amsmath}
```

We need amssymb for `\varnothing` command. We disable `\Bbbk` because it may conflict with some packages from acmart:

```
\let\Bbbk\relax\RequirePackage{amssymb}
```

We need fancyvrb for `\VerbatimEnvironment` command:

```
\RequirePackage{fancyvrb}
```

We need iexec for executing Perl scripts:

```
\RequirePackage{iexec}
```

Then, we process package options:

```
\RequirePackage{pgfopts}
\RequirePackage{ifluatex}
\RequirePackage{ifxetex}
\pgfkeys{
  /eolang/.cd,
  tmpdir/.store in=\eolang@tmpdir,
  tmpdir/.default=_eolang\ifxetex-xe\else\ifluatex-lua\fi\fi,
  nocomments/.store in=\eolang@nocomments,
  anonymous/.store in=\eolang@anonymous,
  tmpdir
}
\ProcessPgfPackageOptions{/eolang}
```

Then, we make a directory where all temporary files will be kept:

```
\iexec[null]{mkdir -p "\eolang@tmpdir/\jobname"}%
```

`\eolang@lineno` Then, we define an internal counter to protect line number from changing:

```
\makeatletter\newcounter{eolang@lineno}\makeatother
```

`\eolang@mdfive` Then, we define a command for MD5 hash calculating of a file:

```
\RequirePackage{pdftexcmds}
\makeatletter
\newcommand\eolang@mdfive[1]{\pdf@filemdfivesum{#1}}
\makeatother
```

`eolang-phi.pl` Then, we create a Perl script for `phiquation` processing using `VerbatimOut` environment from fancyvrb:

```
\makeatletter
\begin{VerbatimOut}{\eolang@tmpdir/eolang-phi.pl}
$macro = $ARGV[0];
open(my $fh, '<', $ARGV[1]);
my $tex; { local $/; $tex = <$fh>; }
print "% This file is auto-generated by 0.12.0\n";
print '% There are ', length($tex),
  ' chars in the input: ', $ARGV[1], "\n";
print '% ---', "\n";
if (index($tex, "\t") > 0) {
  print "TABS are prohibited!";
  exit 1;
}
my @lines = split (/\n/g, $tex);
foreach my $t (@lines) {
  print '% ', $t, "\n";
}
print '% ---', "\n";
$tex =~ s/%.*\n/\n/g;
```

```
$tex =~ s/^\s+|\s+$//g;
my $splitting = $tex =~ /^\\begin\{split\}/;
if ($splitting) {
print '% The manual splitting mode is ON since \begin{split} started the text' . "\n";
}
my $indents = $tex =~ /\n +/g;
my $gathered = (0 == $indents);
if ($gathered) {
  if ($splitting) {
  print '% The "gathered" is NOT used because of manual splitting' . "\n";
  $gathered = 0;
} else {
  print '% The "gathered" is used since all lines are left-aligned' . "\n";
}
} else {
  print '% The "gathered" is NOT used because ' .
    $indents . " lines are indented\n";
}
my $align = 0;
print '% The "align" is NOT used by default' . "\n";
if (index($tex, '&&') >= 0) {
  $macro =~ s/equation/align/g;
  $align = 1;
  print '% The "align" is used because of && seen in the text' . "\n";
}
if ($macro ne 'phiq') {
if (not $splitting) {
   $tex =~ s/\\\\\n/\n\n/g;
  $tex =~ s/\\\n\s*//g;
}
  $tex =~ s/\n*(\\label\{[^\}]+\})\n*/\1/g;
  $tex =~ s/\n{3,}/\n\n/g;
}
my @texts = ();
sub trep {
  my ($s) = @_;
  my $open = 0;
  my $p = 0;
  for (; $p < length($s); $p++) {
    $c = substr($s, $p, 1);
   if ($c eq '}') {
   if ($open eq 0) {
      last;
   }
     $open--;
   }
   if ($c eq '{') {
     $open++;
   }
}
  push(@texts, substr($s, 0, $p));
  return '{TEXT' . (0+@texts - 1) . '}' . substr($s, $p + 1);
}
$tex =~ s/\\text\{(.+)/trep("$1")/ge;
```

```
if (not $splitting) {
$tex =~ s/(?<![{&])&(?![&])/\\sigma{}/g;
}
$tex =~ s/([^\\{a-z0-9]|^)Q(?![a-z0-9])/\1\\Phi{}/g;
$tex =~ s/([^\\{a-z0-9]|^)D>/\1\\Delta{}..>/g;
$tex =~ s/([^\\{a-z0-9]|^)L>/\1\\lambda{}..>/g;
$tex =~ s/"([^"]+)"/|"\1"|/g;
$tex =~ s/(^|(?<=[\s)(\]\[,.>\/]))([a-zA-Z][a-z0-9]+)(?=[\s)(\]\[,.-]|$)/|\2|/g;
$tex =~ s/([^^_]|^)([0-9]+|\*)\/(\\?[a-z]+|\|[a-z]+\|)
  (->|\.\.>|~>|:=|!->)/\1\\alpha_{\2}\\vert{}\3\\space{}\4/xg;
$tex =~ s/([^^_]|^)([0-9]+|\*)
  (->|\.\.>|~>|:=|!->)/\1\\alpha_{\2}\\space{}\3/xg;
if ($macro ne 'phiq') {
  if (not $splitting) {
  $tex =~ s/\\begin\{split\}\n/\\begin{split}&/g;
   $tex =~ s/\n\s*\\end\{split\}/\\end{split}/g;
   $tex =~ s/\n\n/\\\\&/g;
  $tex =~ s/\n/\\phiEOL{}\n&/g;
  $tex =~ s/\\\\$//g;
  $tex =~ s/\\\\/\\\\\n/g;
   $tex =~ s/([^&\s])\s{2}([^\s])/\1 \2/g;
  $tex =~ s/\s{2}/ \\quad{}/g;
   $tex = '&' . $tex;
  }
  my $lead = '[^\s]+\s(?:->|:=|=|==)\s';
  my @leads = $tex =~ /&${lead}/g;
  my @eols = $tex =~ /&/g;
  if (0+@leads == 0+@eols && 0+@eols > 1) {
    $tex =~ s/&(${lead})/\1&~/g;
    $gathered = 0;
  print '% The "gathered" is NOT used because all ' .
    (0+@eols) . ' lines are ' . (0+@leads) . " leads\n";
  }
}
if ($macro ne 'phiq') {
sub strip_tabs {
    my ($env, $tex) = @_;
$tex =~ s/&//g;
  return "\\begin{$env}" . $tex . "\\end{$env}";
  }
  foreach my $e (('matrix', 'cases')) {
$tex =~ s/\\begin\{(\Q$e\E\*?)\}(.+)\\end\{\Q$e\E\*?\}/strip_tabs($1, $2)/sge;
}
}
$tex =~ s/\$/\\xi{}/g;
$tex =~ s/(?<!\{)\^(?!\{)/\\rho{}/g;
$tex =~ s/\[\[/\\llbracket\\mathbin{}/g;
$tex =~ s/\]\]/\\mathbin{}\\rrbracket{}/g;
$tex =~ s/([\s,>(])([0-9A-F]{2}(?:-[0-9A-F]{2})+|
  [0-9]+(?:\.[0-9]+)?)(?!\{)/\1|\2|/xg;
$tex =~ s/TRUE/|TRUE|/g;
$tex =~ s/FALSE/|FALSE|/g;
$tex =~ s/\?/\\varnothing{}/g;
$tex =~ s/@/\\varphi{}/g;
```

```
$tex =~ s/-([a-z]+)>/\\mathrel{\\phiSlot{\1}}/g;
$tex =~ s/!->/\\mathbin{\\phiConst}/g;
$tex =~ s/->/\\mathbin{\\mapsto}/g;
$tex =~ s/~>/\\mathbin{\\phiWave}/g;
$tex =~ s/:=/\\mathrel{\\vDash}/g;
$tex =~ s/==/\\mathrel{\\equiv}/g;
$tex =~ s/\.\.>/\\mathbin{\\phiDotted}/g;
$tex =~ s/<</\\langle/g;
$tex =~ s/>>/\\rangle/g;
$tex =~ s/\|{2,}/|/g;
$tex =~ s/\|([^\|]+)\|/\\textnormal{\\texttt{\1}}{}/g;
$tex =~ s/\{TEXT(\d+)\}/'\\text{' . @texts[$1] . '}';/ge;
if ($macro eq 'phiq') {
  print '$' if ($tex ne '');
} else {
  print '\begin{', $macro, "}\n";
  if (not($align)) {
  if ($gathered) {
    print '\begin{gathered}' . "\n";
  } elsif (not $splitting) {
    print '\begin{split}' . "\n";
  }
  }
}
if ($gathered and not($align)) {
  $tex =~ s/^&//g;
  $tex =~ s/\n&/\n/g;
}
print $tex;
if ($macro eq 'phiq') {
  print '$' if ($tex ne '');
} else {
  if (not($align)) {
  if ($gathered) {
    print "\n" . '\end{gathered}';
  } elsif (not $splitting) {
    print "\n" . '\end{split}';
  }
  }
  print "\n" . '\end{' . $macro . '}';
}
print '\endinput';
\end{VerbatimOut}
\message{eolang: File with Perl script
  '\eolang@tmpdir/eolang-phi.pl' saved^^J}%
\makeatother
```

`\phiSaveTo` Then, we define the `\phiSaveTo` command to instruct the `phiquation` environment that the output should not be sent to the document but saved to the file instead:

```
\makeatletter
\newcommand\phiSaveTo[1]{\def\eolang@phiSaveTo{#1}}
\makeatother
```

`phiquation` Then, we define the `phiquation` and the `phiquation*` environments through a sup-

plementary \eolang@process command:

```
\makeatletter\newcommand\eolang@process[1]{
  \def\hash{\eolang@mdfive
    {\eolang@tmpdir/\jobname/phiquation.tex}}%
  \iexec[null]{cp "\eolang@tmpdir/\jobname/phiquation.tex"
    "\eolang@tmpdir/\jobname/\hash.tex"}%
  \message{Start parsing 'phi' at line no. \the\inputlineno^^J}
  \iexec[trace,stdout=\eolang@tmpdir/\jobname/\hash-post.tex]{
    perl "\eolang@tmpdir/eolang-phi.pl"
    '#1'
    "\eolang@tmpdir/\jobname/\hash.tex"
    \ifdefined\eolang@nocomments | perl -pe 's/\%.*(\\n|$)//g'\fi
    \ifdefined\eolang@phiSaveTo > \eolang@phiSaveTo\fi}%
  \setcounter{FancyVerbLine}{\value{eolang@lineno}}%
  \def\eolang@phiSaveTo{\relax}%
}
%
\newenvironment{phiquation*}%
{\catcode`\|=12 \VerbatimEnvironment%
\setcounter{eolang@lineno}{\value{FancyVerbLine}}%
\begin{VerbatimOut}
  {\eolang@tmpdir/\jobname/phiquation.tex}}
{\end{VerbatimOut}\eolang@process{equation*}}
%
\newenvironment{phiquation}%
{\catcode`\|=12 \VerbatimEnvironment%
\setcounter{eolang@lineno}{\value{FancyVerbLine}}%
\begin{VerbatimOut}
  {\eolang@tmpdir/\jobname/phiquation.tex}}
{\end{VerbatimOut}\eolang@process{equation}}
\makeatother
```

\phiq Then, we define \phiq command:

```
\RequirePackage{xstring}
\makeatletter\newcommand\phiq[1]{%
\StrSubstitute{\detokenize{#1}}{'}{'"'"'}[\clean]%
  \iexec[log,trace,quiet,stdout=\eolang@tmpdir/\jobname/phiq.tex]{
    /bin/echo '\clean'}%
  \def\hash{\eolang@mdfive
    {\eolang@tmpdir/\jobname/phiq.tex}}%
  \iexec[null]{cp "\eolang@tmpdir/\jobname/phiq.tex"
    "\eolang@tmpdir/\jobname/\hash.tex"}%
  \ifdefined\eolang@nodollar\else\catcode`\$=3 \fi%
  \iexec[trace,stdout=\eolang@tmpdir/\jobname/\hash-post.tex]{
    perl \eolang@tmpdir/eolang-phi.pl 'phiq'
    "\eolang@tmpdir/\jobname/\hash.tex"
    \ifdefined\eolang@nocomments | perl -pe 's/\%.*(\\n|$)//g'\fi}%
  \ifdefined\eolang@nodollar\else\catcode`\$\active\fi%
}\makeatother
```

nodollar Then, we redefine dollar sign:

```
\ifdefined\eolang@nodollar\else
  \begingroup
  \catcode`\$=\active
```

```
  \protected\gdef$#1${\phiq{#1}}
  \endgroup
  \AtBeginDocument{\catcode`\$=\active}
\fi
```

eolang-sodg.pl Then, we create a Perl script for sodg graphs processing using VerbatimOut from fancyvrb:

```
\makeatletter
\begin{VerbatimOut}{\eolang@tmpdir/eolang-sodg.pl}
sub num {
  my ($i) = @_;
  $i =~ s/(\+|-)\./\10./g;
  return $i;
}
sub fmt {
  my ($tex) = @_;
  $tex =~ s/\|([^\|]+)\|/\\textnormal{\\texttt{\1}}/g;
  return $tex;
}
sub vertex {
  my ($v) = @_;
  if (index($v, 'v0') == 0) {
    return '\Phi';
  } else {
    $v =~ s/^v/v_/g;
    $v =~ s/[^0-9]$//g;
    return $v;
  }
}
sub tailor {
  my ($t, $m) = @_;
  $t =~ s/<([A-Z]?${m}[A-Z]?):([^>]+)>/\2/g;
  $t =~ s/<[A-Z]+:[^>]+>//g;
  return $t;
}
open(my $fh, '<', $ARGV[0]);
my $tex; { local $/; $tex = <$fh>; }
if (index($tex, "\t") > 0) {
  print "TABS are prohibited!";
  exit 1;
}
print '% This file is auto-generated', "\n%\n";
print '% --- there are ', length($tex),
  ' chars in the input (', $ARGV[0], "):\n";
foreach my $t (split (/\n/g, $tex)) {
  print '% ', $t, "\n";
}
print "% ---\n";
$tex =~ s/\\\\/\n/g;
$tex =~ s/\\\n//g;
$tex =~ s/(\\[a-zA-Z]+)\s+/\1/g;
$tex =~ s/\n{2,}/\n/g;
my @cmds = split(/\n/g, $tex);
print '% --- before processing:' . "\n";
```

```
foreach my $t (split (/\n/g, $tex)) {
  print '% ', $t, "\n";
}
print '% ---';
print ' (' . (0+@cmds) . " lines)\n";
print '\begin{phicture}', "\n";
for (my $c = 0; $c < 0+@cmds; $c++) {
  my $cmd = $cmds[$c];
  $cmd =~ s/^\s+//g;
  $cmd =~ s/%.*//g;
  my ($head, $tail) = split(/ /, $cmd, 2);
  my %opts = {};
  foreach my $p (split(/ /, $tail)) {
    my ($q, $t) = split(/:/, $p);
    $opts{$q} = $t;
  }
  if (index($head, '->') >= 0) {
    my $draw = '\draw[';
    if (exists $opts{'pi'}) {
      $draw = $draw . '<MB:phi-pi><F:draw=none>';
      if (not exists $opts{'a'}) {
        $opts{'a'} = '\pi';
      }
    }
    if (exists $opts{'rho'} and not(exists $opts{'bend'})) {
      $draw = $draw . '<MB:,phi-rho>';
    }
    $draw = $draw . ']';
    my ($from, $to) = split (/->/, $head);
    $draw = $draw . " (${from}) ";
    if (exists $opts{'bend'}) {
      $draw = $draw . 'edge [<F:draw=none><MF:,bend right=' .
        num($opts{'bend'}) . '>';
      if (exists $opts{'rho'}) {
        $draw = $draw . '<MB:,phi-rho>';
      }
      $draw = $draw . ']';
    } else {
      $draw = $draw . '--';
    }
    if (exists $opts{'a'}) {
      my $a = $opts{'a'};
      if (index($a, '$') == -1) {
        $a = '$' . fmt($a) . '$';
      } else {
        $a = fmt($a);
      }
      $draw = $draw . '<MB: node [phi-attr] {' . $a . '}>';
    }
    if (exists $opts{'break'}) {
      $draw = $draw . '<F: coordinate [pos=' .
        ($opts{'break'} / 100) . '] (break)>';
    }
    $draw = $draw . " (<MF:${to}><B:break-v>)";
```

```
354     if (exists $opts{'break'}) {
355       print tailor($draw, 'F') . ";\n";
356       print '  \node[outer sep=.1cm,inner sep=0cm] ' .
357         'at (break) (break-v) {$' . vertex($to) .
358         '$};' . "\n";
359       print '  ' . tailor($draw, 'B');
360     } else {
361       print tailor($draw, 'M');
362     }
363   } elsif (index($head, '=>') >= 0) {
364     my ($from, $to) = split (/=+>/, $head);
365     my $size = () = $head =~ /=/g;
366     if ($from eq '') {
367       print '\node [phi-arrow, left=' . ($size * 0.6) . 'cm of ' .
368         $to . '.center]';
369     } elsif ($to eq '') {
370       print '\node [phi-arrow, right=' . ($size * 0.6) . 'cm of ' .
371         $from . '.center]';
372     } else {
373       print '\node [phi-arrow] at ($(' .
374         $from . ')!0.5!(' . $to . ')$)';
375     }
376     print '{}';
377   } elsif (index($head, '!') >= 0) {
378     my ($v, $marker) = split (/!+/, $head);
379     my $size = () = $head =~ /!/g;
380     print '\node [phi-marker, left=' .
381       ($size * 0.6) . 'cm of ' .
382       $v . '.center]{' . fmt($marker) . '}';
383   } elsif (index($head, '+') >= 0) {
384     my ($v, $suffix) = split (/\+/, $head);
385     my @friends = ($v);
386     foreach my $c (@cmds) {
387       $e = $c;
388       $e =~ s/^\s+//g;
389       my $h = $e;
390       $h = substr($e, 0, index($e, ' ')) if index($e, ' ') >= 0;
391       foreach my $f (@friends) {
392         my $add = '';
393         if (index($h, $f . '->') >= 0) {
394           $add = substr($h, index($h, '->') + 2);
395         }
396         if ($h =~ /->\Q${f}\E$/) {
397           $add = substr($h, 0, index($h, '->'));
398         }
399         if (index($e, ' xy:' . $f . ',') >= 0) {
400           $add = $h;
401         }
402         if (index($add, '+') == -1
403           and $add ne ''
404           and not(grep(/^\Q${add}\E$/, @friends))) {
405           push(@friends, $add);
406         }
407       }
```

```
408     }
409     my @extra = ();
410     foreach my $e (@cmds) {
411       $m = $e;
412       if ($m =~ /^\s*\Q${v}\E\s/) {
413         next;
414       }
415       if ($m =~ /^\s*[^\s]+\+/ and not($m =~ /^\s*\Q${head}\E\s/)) {
416         next;
417       }
418       foreach my $f (@friends) {
419         my $h = $f;
420         $h =~ s/[a-z]$//g;
421         if ($m =~ s/^(\s*)\Q${f}\E\+\Q${suffix}\E\s?/\1${h}${suffix} /g) {
422           last;
423         }
424         $m =~ s/^(\s*)\Q${f}\E\s/\1${h}${suffix} /g;
425         $m =~ s/^(\s*)\Q${f}\E->/\1${h}${suffix}->/g;
426         $m =~ s/\sxy:\Q${f}\E,/ xy:${h}${suffix},/g;
427         $m =~ s/->\Q${f}\E\s/->${h}${suffix} /g;
428       }
429       if ($m ne $e) {
430         push(@extra, ' ' . $m);
431       }
432     }
433     splice(@extra, 0, 0, @extra[-1]);
434     splice(@extra, -1, 1);
435     splice(@extra, 0, 0, '% clone of ' . $v . ' (' . $head .
436       '), friends: [' . join(', ', @friends) . '] in ' .
437       (0+@cmds) . ' lines');
438     splice(@cmds, $c, 1, @extra);
439     print '% cloned ' . $v . ' at line no.' . $c .
440       ' (+' . (0+@extra) . ' lines -> ' .
441       (0+@cmds) . ' lines total)';
442   } elsif ($head =~ /^v[0-9]+[a-z]?$/) {
443     print '\node[';
444     if (exists $opts{'xy'}) {
445       my ($v, $right, $down) = split(/,/, $opts{'xy'});
446       my $loc = '';
447       if ($down > 0) {
448         $loc = 'below ';
449       } elsif ($down < 0) {
450         $loc = 'above ';
451       }
452       if ($right > 0) {
453         $loc = $loc . 'right';
454       } elsif ($right < 0) {
455         $loc = $loc . 'left';
456       }
457       print ',' . $loc . '=';
458       print abs(num($down)) . 'cm and ' .
459         abs(num($right)) . 'cm of ' . $v . '.center';
460     }
461     if (exists $opts{'data'}) {
```

```
      print ',phi-data';
      if ($opts{'data'} ne '') {
        my $d = $opts{'data'};
        if (index($d, '|') == -1) {
          $d = '$\Delta\phiDotted\text{' .
            '\textnormal{\texttt{' . fmt($d) . '}}}$';
        } else {
          $d = fmt($d);
        }
        $opts{'box'} = $d;
      }
    } elsif (exists $opts{'atom'}) {
      print ',phi-atom';
      if ($opts{'atom'} ne '') {
        my $a = $opts{'atom'};
        if (index($a, '$') == -1) {
          $a = '$\lambda\phiDotted{}' . fmt($a) . '$';
        } else {
          $a = fmt($a);
        }
        $opts{'box'} = $a;
      }
    } else {
      print ',phi-object';
    }
    print ']';
    print ' (' . $head . ')';
    print ' {';
    if (exists $opts{'tag'}) {
      my $t = $opts{'tag'};
      if (index($t, '$') == -1) {
        $t = '$' . $t . '$';
      } else {
       $t = fmt($t);
     }
     print $t;
    } else {
      print '$' . vertex($head) . '$';
    }
    print '}';
    if (exists $opts{'box'}) {
      print ' node[phi-box] at (';
      print $head, '.south east) {';
      print $opts{'box'}, '}';
    }
  } else {
    print $cmd;
  }
  print ";\n";
}
print '\end{phicture}%', "\n";
print "% --- after processing:\n%";
foreach my $c (@cmds) {
  print '% ', $c, "\n";
```

```
}
print '% --- (' . (0+@cmds) . " lines)\n";
print '\endinput';
\end{VerbatimOut}
\message{eolang: File with Perl script
  '\eolang@tmpdir/eolang-sodg.pl' saved^^J}%
\makeatother
```

`FancyVerbLine` Then, we reset the counter for fancyvrb, so that it starts counting lines from zero when the document starts rendering:

```
\setcounter{FancyVerbLine}{0}
```

`tikz` Then, we include tikz package and its libraries:

```
\RequirePackage{tikz}
  \usetikzlibrary{arrows}
  \usetikzlibrary{shapes}
  \usetikzlibrary{decorations}
  \usetikzlibrary{decorations.pathmorphing}
  \usetikzlibrary{decorations.pathreplacing}
  \usetikzlibrary{positioning}
  \usetikzlibrary{calc}
  \usetikzlibrary{math}
  \usetikzlibrary{arrows.meta}
```

`phicture` Then, we define internal environment `phicture`:

```
\newenvironment{phicture}%
  {\noindent\begin{tikzpicture}[
    ->,>=stealth',node distance=0,thick,
    pics/parallel arrow/.style={
      code={\draw[-latex,phi-rho] (##1) -- (-##1);}}]}%
  {\end{tikzpicture}}
\tikzstyle{phi-arrow} = [fill=white!80!black, single arrow,
  minimum height=0.5cm, minimum width=0.5cm,
  single arrow head extend=2mm]
\tikzstyle{phi-marker} = [inner sep=0pt, minimum height=1.4em,
  minimum width=1.4em, font={\small\color{white}\ttfamily},
  fill=gray]
\tikzstyle{phi-thing} = [thick,inner sep=0pt,minimum height=2.4em,
  draw,font={\small}]
\tikzstyle{phi-object} = [phi-thing,circle]
\tikzstyle{phi-data} = [phi-thing,regular polygon,
  regular polygon sides=8]
\tikzstyle{phi-empty} = [phi-object]
\tikzset{%
  phi-rho/.style={
    postaction={%
      decoration={
        show path construction,
        curveto code={
          \tikzmath{
            coordinate \I, \F, \v;
            \I = (\tikzinputsegmentfirst);
            \F = (\tikzinputsegmentlast);
            \v = ($(\I) -(\F)$);
```

```
            real \d, \a, \r, \t;
            \d = 0.8;
            \t = atan2(\vy, \vx);
            if \vx<0 then { \a = 90; } else { \a = -90; };
            {
              \draw[arrows={-latex}, decorate,
              decoration={%
                snake, amplitude=.4mm,
                segment length=2mm,
                post length=1mm
              }]
              ($(\F)!.5!(\I) +(\t: -\d em) +(\t +\a: 1ex)$)
              -- ++(\t: 2*\d em);
            };
          }
        },
        lineto code={
          \tikzmath{
            coordinate \I, \F, \v;
            \I = (\tikzinputsegmentfirst);
            \F = (\tikzinputsegmentlast);
            \v = ($(\I) -(\F)$);
            real \d, \a, \r, \t;
            \d = 0.8;
            \t = atan2(\vy, \vx);
            if \vx<0 then { \a = 90; } else { \a = -90; };
            {
              \draw[arrows={-latex}, decorate,
              decoration={%
                snake, amplitude=.4mm,
                segment length=2mm,
                post length=1mm}]
              ($(\F)!.5!(\I) +(\t: -\d em) +(\t +\a: 1ex)$)
              -- ++(\t: 2*\d em);
            };
          }
        }
      },
      decorate
    }
  }
}
\tikzstyle{phi-pi} = [draw,dotted]
\tikzstyle{phi-atom} = [phi-object,double]
\tikzstyle{phi-box} = [xshift=-5pt,yshift=3pt,draw,fill=white,
  rectangle,thin,minimum width=1.2em,anchor=north west,
  font={\scriptsize}]
\tikzstyle{phi-attr} = [midway,sloped,inner sep=0pt,
  above=2pt,sloped/.append style={transform shape},
  font={\scriptsize},color=black]
```

`\sodgSaveTo` Then, we define the `\sodgSaveTo` command to instruct the `sodg` environment that the output should not be sent to the document but saved to the file instead:

```
\makeatletter
```

```
\newcommand\sodgSaveTo[1]{\def\eolang@sodgSaveTo{#1}}
\makeatother
```

`sodg` Then, we create a new environment `sodg`, as suggested here:

```
\makeatletter\newenvironment{sodg}%
{\catcode`\|=12 \VerbatimEnvironment%
\setcounter{eolang@lineno}{\value{FancyVerbLine}}%
\begin{VerbatimOut}
  {\eolang@tmpdir/\jobname/sodg.tex}}
{\end{VerbatimOut}%
  \def\hash{\eolang@mdfive
    {\eolang@tmpdir/\jobname/sodg.tex}}%
  \iexec[null]{cp "\eolang@tmpdir/\jobname/sodg.tex"
    "\eolang@tmpdir/\jobname/\hash.tex"}%
  \catcode`\$=3 %
  \message{Start parsing `sodg' at line no. \the\inputlineno^^J}
  \iexec[trace,stdout=\eolang@tmpdir/\jobname/\hash-post.tex]{
    perl "\eolang@tmpdir/eolang-sodg.pl"
    "\eolang@tmpdir/\jobname/\hash.tex"
    \ifdefined\eolang@nocomments | perl -pe 's/\%.*(\\n|$)//g'\fi
    \ifdefined\eolang@sodgSaveTo > \eolang@sodgSaveTo\fi}%
  \catcode`\$\active%
  \setcounter{FancyVerbLine}{\value{eolang@lineno}}%
  \def\eolang@sodgSaveTo{\relax}%
}\makeatother
```

`\eoAnon` Then, we define a supplementary command to help us anonymize some content.

```
\RequirePackage{hyperref}
\pdfstringdefDisableCommands{
  \def\({}%
  \def\){}%
  \def\alpha{alpha}%
  \def\varphi{phi}%
}
\makeatletter
\NewExpandableDocumentCommand{\eoAnon}{O{ANONYMIZED}m}{%
  \ifdefined\eolang@anonymous%
  \textcolor{orange}{#1}%
  \else%
    #2%
  \fi%
}\makeatother
```

`\eolang` Then, we define a simple supplementary command to help you print EO, the name of our language.

```
\newcommand\eolang{%
  \eoAnon[XYZ]{{\sffamily EO}}}
```

`\phic` Then, we define a simple supplementary command to help you print φ-calculus, the name of our formal apparatus.

```
\newcommand\phic{%
  \eoAnon[\(\alpha\)-cal\-cu\-lus]{\(\varphi\)-cal\-cu\-lus}}
```

`\xmir` Then, we define a simple supplementary command to help you print XMIR, the name of our XML-based format of program representation.

```
\newcommand\xmir{%
  \eoAnon[XML\(^+\)]{XMIR}}
```

`\phiConst` Then, we define a command to render an arrow for a constant attribute, as suggested here:

```
\newcommand\phiConst{%
  \mathrel{\hspace{.15em}}%
  \mapstochar\mathrel{\hspace{-.15em}}\mapsto}
```

`\phiWave` Then, we define a command to render an arrow for a multi-layer attribute, as suggested here:

```
\newcommand\phiWave{%
  \mapstochar\mathrel{\mspace{0.45mu}}\leadsto}
```

`\phiSlot` Then, we define a command to render an arrow for a slot in a basket:

```
\newcommand\phiSlot[1]{%
  \xrightarrow{\text{\sffamily\scshape #1}}}
```

`\phiOset` Then, we define two commands to position a text over and under an arrow, as suggested here:

```
\makeatletter
\newcommand{\phiOset}[2]{%
  \mathrel{\mathop{#2}\limits^{
    \vbox to 0ex{\kern-2\ex@
    \hbox{$\scriptscriptstyle#1$}\vss}}}}
\newcommand{\phiUset}[2]{%
  \mathrel{\mathop{#2}\limits_{
    \vbox to 0ex{\kern-6.3\ex@
    \hbox{$\scriptscriptstyle#1$}\vss}}}}
\makeatother
```

`\phiMany` Then, we define a command for an arrow with iterating indecies:

```
\newcommand\phiMany[3]{%
  \phiOset{#3}{\phiUset{#2}{#1}}}
```

`\phiEOL` Then, we define a command for line breaks in formulas:

```
\newcommand\phiEOL{\\[-4pt]}
```

`\phiDotted` Then, we define a command to render an arrow for a special attribute, as suggested here:

```
\RequirePackage{trimclip}
\RequirePackage{amsfonts}
\makeatletter
\newcommand{\phiDotted}{%
  \mapstochar\mathrel{\mathpalette\phiDotted@\relax}}
\newcommand{\phiDotted@}[2]{%
  \begingroup%
  \settowidth{\dimen\z@}{$\m@th#1\rightarrow$}%
  \settoheight{\dimen\tw@}{$\m@th#1\rightarrow$}%
  \sbox\z@{%
    \makebox[\dimen\z@][s]{%
```

```
      \clipbox{0 0 {0.4\width} 0}%
        {\resizebox{\dimen\z@}{\height}%
          {$\m@th#1\dashrightarrow$}}%
      \hss%
      \clipbox{{0.69\width} {-0.1\height} 0
        {-\height}}{$\m@th#1\rightarrow$}%
    }%
  }%
  \ht\z@=\dimen\tw@ \dp\z@=\z@%
  \box\z@%
  \endgroup%
}
\makeatother
```

References

Bugayenko, Yegor (2021). *EOLANG and φ-calculus*. arXiv: 2111.13384 [cs.PL].
Kudasov, Nikolai et al. (2022). *φ-calculus: a purely object-oriented calculus of decorated objects*. arXiv: 2204.07454 [cs.PL].

Change History

0.0.1

General: First draft. 9

0.0.2

`sodg`: The environment `phigure` renamed to `sodg` for the sake of better semantic. The graph in the picture is solely a SODG graph, that's why the name `sodg` is better. 22

`eolang-phi.pl`: New symbol added for basket slots 10

Parsing of the symbols "`@`," "`^`," and "`&`" enabled (`\varphi`, `\rho`, and `\sigma`) 10

The symbols "`[`" and "`]`" replaced with "`[[`" and "`]]`" for abstract object brackets, because they conflicted with normal square brackets 10

`eolang-sodg.pl`: The Perl file now has a fixed name, which doesn't depend on the name of the TeX job. This file may be shared among jobs, no need to make it uniquely named. 15

`\phiq`: Parsing of additional symbols enabled. 14

0.1.0

General: Parsing of package options introduced. 10

`\eolang`: New command `\eolang` added to print the name of the language in both normal and the anonymous mode of `acmart`. . . . 22

`\eolang@mdfive`: New supplementary command added to calculate MD5 sum of a file. 10

`eolang-phi.pl`: A new Perl script "`eolang-phi.pl`" added for parsing of phi expressions. 10

`eolang-sodg.pl`: There are two Perl scripts now: one for `phiquation`, another one for `sodg`. 15

`\phic`: New command `\phic` prints the name of φ-calculus in both normal and the anonymous mode of `acmart`. 22

`\phiConst`: New command `\phiConst` added to denote a link to a constant attribute. 23

`\phiDotted`: New command `\phiDotted` added to denote a link to a special attribute. 23

0.2.0

`eolang-phi.pl`: Numbers automatically render as `\texttt`. No need to use vertical bars around them anymore. 10

`eolang-sodg.pl`: The content of the `atom` and the `data` boxes is parsed automatically as formulas and numbers, respectively. 15

`\xmir`: New command `\xmir` prints XMIR in both normal and the anonymous mode of `acmart`. . . . 23

0.3.0

`\eolang@lineno`: New counter for protecting lineno. 10

`eolang-phi.pl`: New arrow added, that looks like `\leadsto`. 10

`\phiWave`: New command `\phiWave` added to denote a link to a multi-layer attribute. 23

0.4.0

`eolang-sodg.pl`: Labels on the edges are automatically printed as math formulas. Also, boxes are prefixed with the `\Delta` and the `\lambda` commands. 15

Relative positioning of vertices fixed. 15

0.5.0

`eolang-phi.pl`: Automated formatting of `TRUE` and `FALSE` added. 10

`eolang-sodg.pl`: It is possible to use TikZ commands inside the `sodg` environment. 15

New syntax introduced that allows to make clones of vertices and all their dependants. 15

Now edges may have the `break` attribute, to make them shorter. . . 15

`\phiMany`: New command `\phiMany` enables iterating over an arrow. . . 23

`\phiSlot`: New command `\phiSlot` added to denote a link to a slot in a basket. 23

0.6.0

General: Package option `nocomments` added in order to enable comments suppression in temporary `.tex` files (may be pretty important for `.dtx` documents). 10

`eolang-sodg.pl`: The `rrho` attribute is retired, now `rho` works just fine in all situations. 15
0.7.0
`nodollar`: Now it is possible to use dollar sign instead of the `\phiq` command. 14
`eolang-phi.pl`: New syntax sugar for Φ, just using capital "`Q`" is enough. 10
Object names are automatically converted to `\texttt`, provided their names include two or more symbols. 10
Text in quotes is automatically converted to `\texttt`. 10
0.8.0
General: The `anonymous` package option added. 10
`eolang-phi.pl`: Inside `phiquation` any text inside the `\text` macro is not processed. 10
`eolang-sodg.pl`: The `tag` attribute is introduced for changing labels inside a vertex circle. 15
`\phiOset`: New commands `\phiOset` and `\phiUset` help position text over and under an arrow. 23
`\phiSaveTo`: The output of the `phiquation` environment can be redirected to a file. 13
`\sodgSaveTo`: The output of the `sodg` environment can be redirected to a file. 21
0.9.0
`\eoAnon`: New command `\eoAnon` added. 22
`eolang-phi.pl`: Proper handling of the `matrix` environment. 10
`\phiEOL`: New command `\phiEOL` added, instead of `\\[-4pt]`. 23

Index

Numbers written in italic refer to the page where the corresponding entry is described; numbers underlined refer to the code line of the definition; numbers in roman refer to the code lines where the entry is used.

Symbols

\$ 141, 239, 244, 248, 251, 626, 633
\% 210, 243, 631
\(. 639, 655, 657
\) 640, 655, 657
* 105, 107, 138
\+ 257, 384, 415, 421
\- 655
\. . . 106, 108, 146, 157, 257
\/ 104, 105
\? 149
\[. 104, 143
\{ 44, 73, 96, 111, 112, 138, 142, 146, 162
\} 44, 73, 111, 112, 138, 162
\] 104, 144
\^ 142
\| 105, 160, 161, 217, 224, 262, 617

Numbers

\2 104, 106, 108, 117, 146, 277
\3 . . . . . 106, 108
\4 106

A

\a 563, 566, 574, 585, 588, 595
\active . 244, 248, 251, 633
\alpha 641, 655
\AtBeginDocument . . 251

B

\Bbbk 3
\begin 25, 46, 166, 169, 171, 219, 226, 254, 305, 535, 619
\box 698

C

\catcode 217, 224, 239, 244, 248, 251, 617, 626, 633
\clean 232, 234
\clipbox 689, 693
\color 544

D

\d . . 162, 563, 564, 574, 575, 585, 586, 595, 596
\dashrightarrow . . . 691
\def 198, 201, 213, 235, 614, 622, 635, 639, 640, 641, 642
\Delta 466
\detokenize 232
\dimen 685, 686, 688, 690, 697
\dp 697
\draw . . . 317, 538, 568, 590

E

\E 138, 396, 404, 412, 415, 421, 424, 425, 426, 427
\end 185, 187, 190, 193, 221, 228, 512, 519, 539, 621
\endinput 192, 518
\eoAnon . 637, 653, 655, 657
\eolang 652
\eolang-phi.pl 24
\eolang-sodg.pl . . . 253
\eolang@anonymous 14, 646
\eolang@lineno 19
\eolang@mdfive 20, 201, 235, 622
\eolang@nocomments . . . 13, 210, 243, 631
\eolang@nodollar 239, 244, 246
\eolang@phiSaveTo 198, 211, 213
\eolang@process 200, 221, 228
\eolang@sodgSaveTo 614, 632, 635
\eolang@tmpdir 11, 18, 25, 195, 202, 203, 204, 206, 207, 209, 220, 227, 233, 236, 237, 238, 240, 241, 242, 254, 521, 620, 623, 624, 625, 628, 629, 630
\ex@ 668, 672

F

\F 559, 561, 562, 574, 581, 583, 584, 595
\FancyVerbLine 523

G

\gdef 249

H

\hash . . . 201, 204, 206, 209, 235, 238, 240, 242, 622, 625, 628, 630
\hbox 669, 673
\height 690, 693, 694
\hspace 659, 660
\hss 692
\ht 697

I

\I 559, 560, 562, 574, 581, 582, 584, 595
\iexec . . . 18, 203, 206, 233, 237, 240, 624, 628
\ifdefined 210, 211, 239, 243, 244, 246, 631, 632, 646
\ifluatex 12
\ifxetex 12
\inputlineno . . . 205, 627

J

\jobname . 18, 202, 203, 204, 206, 209, 220, 227, 233, 236, 237, 238, 240, 242, 620, 623, 624, 625, 628, 630

K

\kern 668, 672

L

\lambda 478
\leadsto 662
\limits 667, 671

M

\m@th . . . 685, 686, 691, 694
\makeatletter 19, 21, 24,

197, 200, 231, 253, 613, 616, 644, 665, 680
\makeatother 19, 23, 196, 199, 229, 245, 522, 615, 636, 651, 674, 701
\makebox 688
\mapsto 660
\mapstochar . 660, 662, 682
\mathop 667, 671
\mathpalette 682
\mathrel 659, 660, 662, 667, 671, 682
\message 194, 205, 520, 627
\mspace 662

N

\newcommand 22, 198, 200, 231, 614, 652, 654, 656, 658, 661, 663, 666, 670, 675, 677, 681, 683
\newcounter 19
\newenvironment 216, 223, 534, 616
\NewExpandableDocumentCommand 645
\node 356, 367, 370, 373, 380, 443
\nodollar 246
\noindent 535

P

\pdf@filemdfivesum . 22
\pdfstringdefDisableCommands 638
\pgfkeys 9
\Phi 268
\phic 654
\phiConst 658
\phicture 534
\phiDotted . 466, 478, 678
\phiDotted@ 682, 683
\phiEOL 677
\phiMany 675
\phiOset 665, 676
\phiq 230, 249
\phiquation 200
\phiSaveTo 197
\phiSlot 663
\phiUset 670, 676
\phiWave 661
\pi 321
\ProcessPgfPackageOptions 17
\protected 249

Q

\Q 138, 396, 404, 412, 415, 421, 424, 425, 426, 427

R

\relax 3, 213, 635, 682
\RequirePackage . . 1, 2, 3, 4, 5, 6, 7, 8, 20, 230, 524, 637, 678, 679
\resizebox 690
\rightarrow . 685, 686, 694

S

\sbox 687
\scriptscriptstyle 669, 673
\scriptsize 609, 612
\scshape 664
\setcounter 212, 218, 225, 523, 618, 634
\settoheight 686
\settowidth 685
\sffamily 653, 664
\small 544, 547
\sodg 616
\sodgSaveTo 613
\StrSubstitute 232
\sxy 426

T

\t 33, 283, 563, 565, 574, 575, 585, 587, 595, 596
\text 466, 664
\textcolor 647
\textnormal 467
\texttt 467
\the 205, 627
\tikz 524
\tikzinputsegmentfirst 560, 582
\tikzinputsegmentlast 561, 583
\tikzmath 558, 580
\tikzset 552
\tikzstyle 540, 543, 546, 548, 549, 551, 605, 606, 607, 610
\ttfamily 544
\tw@ 686, 697

U

\usetikzlibrary . . . 525, 526, 527, 528, 529, 530, 531, 532, 533

V

\v 559, 562, 581, 584
\value 212, 218, 225, 618, 634
\varphi 642, 655
\vbox 668, 672
\VerbatimEnvironment 217, 224, 617
\vss 669, 673
\vx 565, 566, 587, 588
\vy 565, 587

W

\width 689, 693

X

\xmir 656
\xrightarrow 664

Z

\z@ 685, 687, 688, 690, 697, 698