temporal-logic

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Version 1.0

Abstract

The *temporal-logic* package defines functions for rendering temporal operators defined in *Linear Temporal Logic* (LTL)[1], *Metric Temporal Logic* (MTL)[2], *Metric First-order Temporal Logic* (MFOTL)[3], and the *Counting Metric First-order Temporal Binding Logic* (CMFTBL)[4]. The package defines various functions with variants in order to include or omit optional parameters of the operators like the optional interval.

[1] Pnueli, A. (1977). The temporal logic of programs. In: 18th Annual Symposium on Foundations of Computer Science (SFCS 1977). IEEE. https://doi.org/10.1109/SFCS.1977.32.

[2] Alur, R., Henzinger, T. A. (1993). Real-time logics: Complexity and expressiveness. In: Proceedings of the Fifth Annual Symposium on Logic in Computer Science (LICS 1990). Elsevier. https://doi.org/10.1006/inco.1993.1025.

[3] Basin, David, Klaedtke, Felix, Müller, Samuel, and Zălinescu, Eugen. (2015). Monitoring Metric First-order Temporal Properties. In: Journal of the ACM (J. ACM). Association for Computing Machinery. https://doi.org/10.1145/2699444.

[4] Schallau, T., Naujokat, S., Kullmann, F., Howar, F. (2024). Tree-Based Scenario Classification. In: NASA Formal Methods (NFM 2024). Lecture Notes in Computer Science, vol 14627. Springer, Cham. https://doi.org/10.1007/978-3-031-60698-4_15.

Contents

1 Introduction

1.1 Basic usage

This package defines the symbols used in Temporal logics as *MathOperators*. Therefore, the symbols, as well as the commands, have to be used in math mode. To use normal text in the parameters `\mathrm` or `\text` may be used.
The symbols come in two variants: A standalone version for mentioning logic symbols in text without additional formula spacing and a formula version, also providing additional parameters. The formula version should always be preferred over the standalone symbols in formulas as they provide additional spaces and explicitly enforce the correct usage of superscript and subscript via mandatory parameters. The naming scheme of the operators is chosen such that each command reflects the name of the temporal operator prefixed with a "tl" for *temporal logic*. Standalone symbols, as described in Sect. 4, are prefixed with "tlop". Those prefixes are necessary to prevent name clashes with built-in LaTeX commands.

1.2 Package options

Each operator is available as a *bold*, *calligraphic*, and *symbolic* version (if available). Details are described in sections 2.1–2.6 The displayed version can be switched by passing an optional package option:

`displaymode=bold`	`Bold display mode`
`displaymode=caligraphic`	`Caligraphic display mode`
`displaymode=symbol`	`Symbol display mode (default)`

For brevity, `displaymode=` can be omitted.
The superscripts and subscripts are automatically captured by `mathrm` / `mathit`. To switch bewteen roman and italic display, the `scriptmode` can be passed:

`scriptmode=roman`	`Roman script mode (default)`
`scriptmode=italic`	`Italic script mode`

For brevity, `scriptmode=` can be omitted. This setting can be locally overridden by capturing the individual parameters into another `mathrm` / `mathit`.

1.3 Manual structure

This manual is structured as follows. First, the symbols for *Future LTL* and *Past LTL* are introduced in Sect. 2.1 and Sect. 2.2. The additional intervals from *MTL* are described in Sect. 2.3. The operators introduced in *MFOTL* and *CMFTBL* are described in Sect. 2.4 and Sect. 2.5. Additional operators are defined in Sect. 2.6. Section 3 shows the usage of the symbols in formulas. Section 4 closes the command definitions with the standalone symbols for usage in text.

2 Symbol definitions

2.1 Future LTL symbols

Future LTL, or simply *LTL*, defines operators to argue about the future. This includes the following operators.

```
\tlnext          \tlnext \varphi
\tlfinally       \tlfinally \varphi
\tleventually    \tleventually \varphi
\tlglobally      \tlglobally \varphi
\tluntil         \varphi \tluntil \psi
\tlrelease       \psi \tlrelease \varphi
\tlweakuntil     \varphi \tlweakuntil \psi
\tlstrongrelease \psi \tlstrongrelease \varphi
\tlmightyrelease \psi \tlmightyrelease \varphi
```

The symbols get rendered according to the selected display mode (cf. Sect. 1.2). The symbols and the common semantics of the operators are listed below:

Command	Bold	Textual	Symbolic	Semantics
`\tlnext`	$\mathbf{X}\,\varphi$	$\mathcal{X}\,\varphi$	$\bigcirc\,\varphi$	φ must hold at the next state.
`\tlfinally` `\tleventually`	$\mathbf{F}\,\varphi$	$\mathcal{F}\,\varphi$	$\Diamond\,\varphi$	φ must hold at least once in the future.
`\tlglobally`	$\mathbf{G}\,\varphi$	$\mathcal{G}\,\varphi$	$\Box\,\varphi$	φ must hold from now for the entire trace.
`\tluntil`	$\varphi\ \mathbf{U}\,\psi$	$\varphi\ \mathcal{U}\,\psi$	$\varphi\ \mathcal{U}\,\psi$	φ must hold at least until ψ holds, which must hold at the current or a future position.
`\tlrelease`	$\psi\ \mathbf{R}\,\varphi$	$\psi\ \mathcal{R}\,\varphi$	$\psi\ \mathcal{R}\,\varphi$	φ must hold until and including the point where ψ first becomes true. If ψ never becomes true, φ must remain true for the entire trace.
`\tlweakuntil`	$\varphi\ \mathbf{W}\,\psi$	$\varphi\ \mathcal{W}\,\psi$	$\varphi\ \mathcal{W}\,\psi$	φ must hold at least until ψ holds. If ψ never becomes true, ϕ must remain true for the entire trace.
`\tlstrongrelease` `\tlmightyrelease`	$\psi\ \mathbf{M}\,\varphi$	$\psi\ \mathcal{M}\,\varphi$	$\psi\ \mathcal{M}\,\varphi$	φ must hold until and including the point where ψ first becomes true, which must hold at the current or a future position.

2.2 Past LTL symbols

Past LTL defines operators analogous to *Future LTL* to argue about the past. The symbols are identical but are filled solid black.

```
\tlyesterday     \tlyesterday \varphi
\tlprevious      \tlprevious \varphi
\tlonce          \tlonce \varphi
\tlhistorically  \tlhistorically \varphi
\tlsince         \varphi \tlsince \psi
\tlbackto        \psi \backto \varphi
\tlweaksince     \varphi \tlweaksince \psi
\tltrigger       \psi \tltrigger \varphi
```

Command	Bold	Textual	Symbolic	Semantics
`\tlyesterday` `\tlprevious`	$\mathbf{Y}\,\varphi$	$\mathcal{Y}\,\varphi$	$\bullet\,\varphi$	φ must have held at the previous state.
`\tlonce`	$\mathbf{O}\,\varphi$	$\mathcal{O}\,\varphi$	$\blacklozenge\,\varphi$	φ must have held at least once in the past.
`\tlhistorically`	$\mathbf{H}\,\varphi$	$\mathcal{H}\,\varphi$	$\blacksquare\,\varphi$	φ must have held until now for the entire past trace.
`\tlsince`	$\varphi\ \mathbf{S}\,\psi$	$\mathcal{S}\,\varphi$	$\mathcal{S}\,\varphi$	φ must have held since ψ has held, which must have held at the current or a past state.
`\tlbackto`	$\psi\ \mathbf{B}\,\varphi$	$\mathcal{B}\,\varphi$	$\mathcal{B}\,\varphi$	φ must have held since and including the point where ψ was true the last time. If ψ never was true, φ must have been true for the entire past trace.
`\tlweaksince`	$\varphi\ \mathbf{WS}\,\psi$	$\mathcal{WS}\,\varphi$	$\mathcal{WS}\,\varphi$	φ must have held since ψ has held. If ψ never was true, φ must have been true for the entire past trace.
`\tltrigger`	$\psi\ \mathbf{T}\,\varphi$	$\mathcal{T}\,\varphi$	$\mathcal{T}\,\varphi$	φ must have held since and including the point where ψ was true the last time, which must have held at the current or a past state.

2.3 MTL extension

The *Future LTL* and *Past LTL* operators may be extended with an optional interval to form *full MTL*, or simply *MTL*.

`\tlnext`	`\tlnext[`⟨*Interval*⟩`]`	$\bigcirc_{[0,1]}$
`\tlfinally`	`\tlfinally[`⟨*Interval*⟩`]`	$\Diamond_{[0,1]}$
`\tleventually`	`\tleventually[`⟨*Interval*⟩`]`	$\Diamond_{[0,1]}$
`\tlglobally`	`\tlglobally[`⟨*Interval*⟩`]`	$\Box_{[0,1]}$
`\tluntil`	`\tluntil[`⟨*Interval*⟩`]`	$\mathcal{U}_{[0,1]}$
`\tlrelease`	`\tlrelease[`⟨*Interval*⟩`]`	$\mathcal{R}_{[0,1]}$
`\tlweakuntil`	`\tlweakuntil[`⟨*Interval*⟩`]`	$\mathcal{W}_{[0,1]}$
`\tlstrongrelease`	`\tlstrongrelease[`⟨*Interval*⟩`]`	$\mathcal{M}_{[0,1]}$
`\tlmightyrelease`	`\tlmightyrelease[`⟨*Interval*⟩`]`	$\mathcal{M}_{[0,1]}$
`\tlyesterday`	`\tlyesterday[`⟨*Interval*⟩`]`	$\bullet_{[0,1]}$
`\tlprevious`	`\tlprevious[`⟨*Interval*⟩`]`	$\bullet_{[0,1]}$
`\tlonce`	`\tlonce[`⟨*Interval*⟩`]`	$\blacklozenge_{[0,1]}$
`\tlhistorically`	`\tlhistorically[`⟨*Interval*⟩`]`	$\blacksquare_{[0,1]}$
`\tlsince`	`\tlsince[`⟨*Interval*⟩`]`	$\mathcal{S}_{[0,1]}$
`\tlbackto`	`\tlbackto[`⟨*Interval*⟩`]`	$\mathcal{B}_{[0,1]}$
`\tlweaksince`	`\tlweaksince[`⟨*Interval*⟩`]`	$\mathcal{WS}_{[0,1]}$
`\tltrigger`	`\tltrigger[`⟨*Interval*⟩`]`	$\mathcal{T}_{[0,1]}$

The semantics of the intervals are commonly defined as follows: The trace is only evaluated in the given interval. An empty interval is considered to be $[0, \infty)$ for future and $(\infty, 0]$ for past operators. The first component of the interval always indicates the earlier state for both future and past operators. Unmatched brackets can be generated using an extra group: `\tlnext[{[0,∞)}]` $\implies \bigcirc_{[0,\infty)}$.

2.4 MFOTL extension

MFOTL introduces the first-order quantifiers ∃ and ∀. This package does not provide additional symbols, as the built-in ones already contained in LaTeX may be used.

`\exists`	`\exists`	$\exists$
`\forall`	`\forall`	$\forall$

2.5 CMFTBL extension

CMFTBL extends *MFOTL* by the operators *minPrevalence*, *maxPrevalence*, their past forms, and the *bind* operator.

`\tlminprevalence`	`\tlminprevalence{⟨Percentage⟩}[⟨Interval⟩]`	$\triangledown^{0.8}_{[0,1]}$
`\tlpastminprevalence`	`\tlpastminprevalence{⟨Percentage⟩}[⟨Interval⟩]`	$\blacktriangledown^{0.8}_{[0,1]}$
`\tlmaxprevalence`	`\tlmaxprevalence{⟨Percentage⟩}[⟨Interval⟩]`	$\triangle^{0.8}_{[0,1]}$
`\tlpastmaxprevalence`	`\tlpastmaxprevalence{⟨Percentage⟩}[⟨Interval⟩]`	$\blacktriangle^{0.8}_{[0,1]}$
`\tlbind`	`\tlbind{⟨Valuation⟩}{⟨Variable⟩}`	$\downarrow^{\text{v.id}}_{\text{i}}$

The symbols only have a symbolic representation and get rendered independent from the selected display mode (cf. Sect. 1.2). The symbols and the semantics of the operators are listed below:

Command	Symbolic	Semantics
`\tlminprevalence`	$\triangledown^{\text{p}}_{\text{I}}\ \varphi$	φ must hold in at least fraction p of the future states in the interval I.
`\tlpastminprevalence`	$\blacktriangledown^{\text{p}}_{\text{I}}\ \varphi$	φ must have held in at least fraction p of the past states in the interval I.
`\tlmaxprevalence`	$\triangle^{\text{p}}_{\text{I}}\ \varphi$	φ must hold in at most fraction p of the future states in the interval I.
`\tlpastmaxprevalence`	$\blacktriangle^{\text{p}}_{\text{I}}\ \varphi$	φ must have held in at most fraction p of the past states in the interval I.
`\tlbind`	$\downarrow^{\text{v.id}}_{\text{i}}$	Saves the valuation v.id to the variable i for later use in a nested formula, where v already has a new value.

minPrevalence and *maxPrevalence* take the desired percentage as another mandatory parameter. These operators may only be defined on finite traces since they argue about numbers of states. *bind* has no optional interval but two mandatory arguments: the value to bind and the target variable.

2.6 Additional operators

For convenience, the package contains four additional operators:

```
\tlrise      \tlrise \varphi
\tlfall      \tlfall \varphi
\tlprophecy  \tlprophecy \varphi
\tlhistory   \tlhistory \varphi
```

The symbols only have a symbolic representation and get rendered independent from the selected display mode (cf. Sect. 1.2). The symbols and the semantics of the operators are listed below:

Command	Symbolic	Semantics
`\tlrise`	$\nearrow \varphi$	Holds when φ becomes true, i.e. φ holds at this time but did not hold in the immediate past.
`\tlfall`	$\searrow \varphi$	Holds when φ becomes false, i.e. φ does not hold at this time but held in the immediate past.
`\tlprophecy`	$\triangleright \varphi$	Holds when there exists a first moment in the future where φ holds, and the moment is in the interval.
`\tlhistory`	$\triangleleft \varphi$	Holds when there exists a last moment in the past where φ held, and the moment is in the interval.

3 Usage in formulas

The commands may be directly used in math mode to create composite formulas. For the unary formulas, the term φ should directly follow the symbol:

```
\tleventually\varphi        ◊ φ
\tlglobally[[0,1]]\varphi   □[0,1] φ
```

The binary symbols like *until* should be used with two formulas φ and ψ directly before and after the symbol:

```
\varphi\tluntil\psi          φ 𝒰 ψ
\varphi\tluntil[[0,1]]\psi   φ 𝒰[0,1] ψ
```

The *CMFTBL* operators may be used as the unary ones:

```
\tlminprevalence{0.8}\varphi                  ▽0.8 φ
\tlpastmaxprevalence{0.8}[[0,1]]\varphi       △0.8[0,1] φ
\tlbind{v.id}{i}\varphi                       ↓v.id_i φ
```

4 Standalone symbols

The package defines all symbols as a standalone version as *MathOperators* without additional spacing around for the usage in text.

`\tlopnext`	`\tlopnext`	$\bigcirc$
`\tlopfinally`	`\tlopfinally`	$\Diamond$
`\tlopeventually`	`\tlopeventually`	$\Diamond$
`\tlopglobally`	`\tlopglobally`	$\Box$
`\tlopuntil`	`\tlopuntil`	$\mathcal{U}$
`\tloprelease`	`\tloprelease`	$\mathcal{R}$
`\tlopweakuntil`	`\tlopweakuntil`	$\mathcal{W}$
`\tlopstrongrelease`	`\tlopstrongrelease`	$\mathcal{M}$
`\tlopmightyrelease`	`\tlopmightyrelease`	$\mathcal{M}$
`\tlyesterday`	`\tlopyesterday`	$\bullet$
`\tlprevious`	`\tlopprevious`	$\bullet$
`\tlonce`	`\tloponce`	$\blacklozenge$
`\tlhistorically`	`\tlophistorically`	$\blacksquare$
`\tlsince`	`\tlopsince`	$\mathcal{S}$
`\tlbackto`	`\tlopbackto`	$\mathcal{B}$
`\tlweaksince`	`\tlopweaksince`	$\mathcal{WS}$
`\tltrigger`	`\tloptrigger`	$\mathcal{T}$
`\tlopminprevalence`	`\tlopminprevalence{}`	$\triangledown$
`\tloppastminprevalence`	`\tloppastminprevalence{}`	$\blacktriangledown$
`\tlopmaxprevalence`	`\tlopmaxprevalence{}`	$\triangle$
`\tloppastmaxprevalence`	`\tloppastmaxprevalence{}`	$\blacktriangle$
`\tlopbind`	`\tlopbind{}{}`	$\downarrow$
`\tloprise`	`\tloprise`	$\nearrow$
`\tlopfall`	`\tlopfall`	$\searrow$
`\tlopprophecy`	`\tlopprophecy`	$\triangleright$
`\tlophistory`	`\tlophistory`	$\triangleleft$

5 Dependencies

The package loads the following dependencies:

- *expl3* For LaTeX3 support.
- *l3keys2e* For package option parsing.
- *xparse* For parsing the mandatory and optional arguments.
- *amsmath* For symbol definitions.
- *tikz* For rendering of symbols.

6 License

7 Sourcecode

```
% <*package>

\ProvidesExplPackage
 {temporal-logic}
 { 2026-01-06 }
 { v1.1 }
 { Symbols for Temporal Logics }

\RequirePackage{expl3}
\RequirePackage{l3keys2e}
\RequirePackage{xparse}
\RequirePackage{amsmath}
\RequirePackage{tikz}

\ExplSyntaxOn

\msg_new:nnn { temporallogic } { multiple-display-modes }
{ Multiple~display~mode~options~given;~using~the~last~one. }

\msg_new:nnn { temporallogic } { multiple-script-modes }
{ Multiple~script~mode~options~given;~using~the~last~one. }

\int_new:N \g_temporallogic_display_mode_int
\int_new:N \g_temporallogic_script_mode_int
\int_new:N \g_temporallogic_display_mode_count_int
\int_new:N \g_temporallogic_script_mode_count_int
\int_const:Nn \c_temporallogic_display_mode_bold     { 1 }
\int_const:Nn \c_temporallogic_display_mode_letter   { 2 }
\int_const:Nn \c_temporallogic_display_mode_symbolic { 3 }
\int_const:Nn \c_temporallogic_script_mode_roman     { 1 }
\int_const:Nn \c_temporallogic_script_mode_italic    { 2 }

\keys_define:nn { temporallogic }
{
    displaymode .choice:,

    displaymode / bold .code:n =
    {
        \int_gset:Nn \g_temporallogic_display_mode_int
        { \c_temporallogic_display_mode_bold }
        \int_gincr:N \g_temporallogic_display_mode_count_int
    },

    displaymode / letter .code:n =
    {
        \int_gset:Nn \g_temporallogic_display_mode_int
        { \c_temporallogic_display_mode_letter }
        \int_gincr:N \g_temporallogic_display_mode_count_int
    },

    displaymode / symbolic .code:n =
    {
```

```
        \int_gset:Nn \g_temporallogic_display_mode_int
        { \c_temporallogic_display_mode_symbolic }
        \int_gincr:N \g_temporallogic_display_mode_count_int
    },

    % default
    displaymode .initial:n = symbolic,

    % short forms
    bold      .meta:n = { displaymode = bold },
    letter    .meta:n = { displaymode = letter },
    symbolic  .meta:n = { displaymode = symbolic },

    scriptmode .choice:,
    scriptmode / roman .code:n =
    {
        \int_gset:Nn \g_temporallogic_script_mode_int
        { \c_temporallogic_script_mode_roman }
        \int_gincr:N \g_temporallogic_script_mode_count_int
    },
    scriptmode / italic .code:n =
    {
        \int_gset:Nn \g_temporallogic_script_mode_int
        { \c_temporallogic_script_mode_italic }
        \int_gincr:N \g_temporallogic_script_mode_count_int
    },
    scriptmode .initial:n = roman,

    % short forms
    roman  .meta:n = { scriptmode = roman },
    italic .meta:n = { scriptmode = italic },
}

\ProcessKeysOptions { temporallogic }

\int_compare:nNnT { \g_temporallogic_display_mode_count_int } > { 2 }
{
    \msg_warning:nn { temporallogic } { multiple-display-modes }
}

\int_compare:nNnT { \g_temporallogic_script_mode_count_int } > { 2 }
{
    \msg_warning:nn { temporallogic } { multiple-script-modes }
}



\cs_new:Nn \__temporal_logic_op_sup_sub:Nnn {
      \ensuremath {
        #1
        \int_case:nnF { \g_temporallogic_script_mode_int }
        {
            {
                \c_temporallogic_script_mode_roman}  {
```

```
                    \tl_if_empty:nF { #2 } { \c_math_superscript_token
                        { \,\mathrm{#2} } }
                    \tl_if_empty:nF { #3 } { \c_math_subscript_token
                        { \,\mathrm{#3} } }
            }
            {
                \c_temporallogic_script_mode_italic} {
                    \tl_if_empty:nF { #2 } { \c_math_superscript_token
                        { \,\mathit{#2} } }
                    \tl_if_empty:nF { #3 } { \c_math_subscript_token
                        { \,\mathit{#3} } }
                }
            }{}
        \,
      }
}
\cs_generate_variant:Nn \__temporal_logic_op_sup_sub:Nnn { cnn }

\cs_new:Nn \__temporal_logic_op_sup:Nn
{ \__temporal_logic_op_sup_sub:Nnn { #1 } { #2 } {} }
\cs_generate_variant:Nn \__temporal_logic_op_sup:Nn { cn }

\cs_new:Nn \__temporal_logic_op_sub:Nn
{ \__temporal_logic_op_sup_sub:Nnn { #1 } { } { #2 } }
\cs_generate_variant:Nn \__temporal_logic_op_sub:Nn { cn }

\cs_new:Nn \__temporal_logic_op:N
{ \__temporal_logic_op_sup_sub:Nnn { #1 } { } { } }
\cs_generate_variant:Nn \__temporal_logic_op:N { c }

\dim_new:N \__temporal_logic_fht_dim
\cs_new:Nn \__temporal_logic_ex: { \dim_use:N \__temporal_logic_fht_dim }

\cs_new:Nn \__temporal_logic_render_op:n {
  \dim_set:Nn \__temporal_logic_fht_dim {\fontcharht\font`X}
  \tikz[execute~at~end~picture={
       \useasboundingbox (0, 0)
       rectangle
       (\__temporal_logic_ex:, \__temporal_logic_ex:);
  }]{
    \group_begin:
      \cs_set_eq:NN \EX \__temporal_logic_ex:
      #1
    \group_end:
  }
}



\ProvideDocumentCommand \tldisplaymode {} {
    \int_case:nnF { \g_temporallogic_display_mode_int }
    {
        {\c_temporallogic_display_mode_bold}     { Bold }
        {\c_temporallogic_display_mode_letter}   { Letter }
```

```
        {\c_temporallogic_display_mode_symbolic} { Symbolic }
    }{}
}
\ProvideDocumentCommand \tlscriptmode {} {
    \int_case:nnF { \g_temporallogic_script_mode_int }
    {
        {\c_temporallogic_script_mode_roman}  { Roman }
        {\c_temporallogic_script_mode_italic} { Italic }
    }{}
}



% Next
\DeclareMathOperator { \tlboldnext } {
    \ensuremath\mathbf{X}
}
\DeclareMathOperator { \tlletternext } {
    \ensuremath\mathcal{X}
}
\DeclareMathOperator { \tlsymbnext } {
    \__temporal_logic_render_op:n {
        \draw
        (.5*\EX, .5*\EX)
        circle
        (.4*\EX);
    }
}
\ProvideDocumentCommand { \tlnext } { O{} } {
    \__temporal_logic_op_sub:cn {
        \int_case:nnF { \g_temporallogic_display_mode_int }
        {
            {\c_temporallogic_display_mode_bold}     { tlboldnext }
            {\c_temporallogic_display_mode_letter}   { tlletternext }
            {\c_temporallogic_display_mode_symbolic} { tlsymbnext }
        }{}
    } { #1 }
}
\ProvideDocumentCommand { \tlopnext } { } { \tlnext\! }



% Finally
\DeclareMathOperator { \tlboldfinally } {
    \ensuremath\mathbf{F}
}
\DeclareMathOperator { \tlletterfinally } {
    \ensuremath\mathcal{F}
}
\DeclareMathOperator { \tlsymbfinally } {
    \__temporal_logic_render_op:n {
        \draw
        (.5*\EX, 0) --
        (.2*\EX, .5*\EX) --
```

```
        (.5*\EX, \EX) --
        (.8*\EX, .5*\EX) --
        cycle;
    }
}
\ProvideDocumentCommand { \tlfinally } { O{} } {
    \__temporal_logic_op_sub:cn {
        \int_case:nnF { \g_temporallogic_display_mode_int }
        {
            {\c_temporallogic_display_mode_bold}     { tlboldfinally }
            {\c_temporallogic_display_mode_letter}   { tlletterfinally }
            {\c_temporallogic_display_mode_symbolic} { tlsymbfinally }
        }{}
    } { #1 }
}
\ProvideDocumentCommand { \tlopfinally } { } { \tlfinally\! }



% Eventually
\DeclareMathOperator { \tlboldeventually } { \tlboldfinally }
\DeclareMathOperator { \tllettereventually } { \tlletterfinally }
\DeclareMathOperator { \tlsymbeventually } { \tlsymbfinally }
\ProvideDocumentCommand { \tleventually } { O{} } {
    \__temporal_logic_op_sub:cn {
        \int_case:nnF { \g_temporallogic_display_mode_int }
        {
            {\c_temporallogic_display_mode_bold}     { tlboldeventually }
            {\c_temporallogic_display_mode_letter}   { tllettereventually }
            {\c_temporallogic_display_mode_symbolic} { tlsymbeventually }
        }{}
    } { #1 }
}
\ProvideDocumentCommand { \tlopeventually } { } { \tleventually\! }


% Globally
\DeclareMathOperator { \tlboldglobally } {
    \ensuremath\mathbf{G}
}
\DeclareMathOperator { \tllletterglobally } {
    \ensuremath\mathcal{G}
}
\DeclareMathOperator { \tlsymbglobally } {
    \__temporal_logic_render_op:n {
        \draw
        (.15*\EX, .15*\EX)
        rectangle
        (.85*\EX, .85*\EX);
    }
}
\ProvideDocumentCommand { \tlglobally } { O{} } {
    \__temporal_logic_op_sub:cn {
        \int_case:nnF { \g_temporallogic_display_mode_int }
```

```
        {
            {\c_temporallogic_display_mode_bold}     { tlboldglobally }
            {\c_temporallogic_display_mode_letter}   { tlletterglobally }
            {\c_temporallogic_display_mode_symbolic} { tlsymbglobally }
        }{}
    } { #1 }
}
\ProvideDocumentCommand { \tlopglobally } { } { \tlglobally\! }



% Until
\DeclareMathOperator { \tlbolduntil } {
    \medspace\ensuremath\mathbf{U}
}
\DeclareMathOperator { \tlletteruntil } {
    \medspace\ensuremath\mathcal{U}
}
\DeclareMathOperator { \tlsymbuntil } {
    \medspace\ensuremath\mathcal{U}
}
\ProvideDocumentCommand { \tluntil } { O{} } {
    \__temporal_logic_op_sub:cn {
        \int_case:nnF { \g_temporallogic_display_mode_int }
        {
            {\c_temporallogic_display_mode_bold}     { tlbolduntil }
            {\c_temporallogic_display_mode_letter}   { tlletteruntil }
            {\c_temporallogic_display_mode_symbolic} { tlsymbuntil }
        }{}
    } { #1 }
}
\ProvideDocumentCommand { \tlopuntil } { } { \negmedspace\tluntil\! }



% Release
\DeclareMathOperator { \tlboldrelease } {
    \medspace\ensuremath\mathbf{R}
}
\DeclareMathOperator { \tlletterrelease } {
    \medspace\ensuremath\mathcal{R}
}
\DeclareMathOperator { \tlsymbrelease } {
    \medspace\ensuremath\mathcal{R}
}
\ProvideDocumentCommand { \tlrelease } { O{} } {
    \__temporal_logic_op_sub:cn {
        \int_case:nnF { \g_temporallogic_display_mode_int }
        {
            {\c_temporallogic_display_mode_bold}     { tlboldrelease }
            {\c_temporallogic_display_mode_letter}   { tlletterrelease }
            {\c_temporallogic_display_mode_symbolic} { tlsymbrelease }
        }{}
    } { #1 }
```

```
}
\ProvideDocumentCommand { \tloprelease } { } { \negmedspace\tlrelease\! }



% Weak until
\DeclareMathOperator { \tlboldweakuntil } {
    \medspace\ensuremath\mathbf{W}
}
\DeclareMathOperator { \tlletterweakuntil } {
    \medspace\ensuremath\mathcal{W}
}
\DeclareMathOperator { \tlsymbweakuntil } {
    \medspace\ensuremath\mathcal{W}
}
\ProvideDocumentCommand { \tlweakuntil } { O{} } {
    \__temporal_logic_op_sub:cn {
        \int_case:nnF { \g_temporallogic_display_mode_int }
        {
            {\c_temporallogic_display_mode_bold}     { tlboldweakuntil }
            {\c_temporallogic_display_mode_letter}   { tlletterweakuntil }
            {\c_temporallogic_display_mode_symbolic} { tlsymbweakuntil }
        }{}
    } { #1 }
}
\ProvideDocumentCommand { \tlopweakuntil } { } { \negmedspace\tlweakuntil\! }



% Strong Release
\DeclareMathOperator { \tlboldstrongrelease } {
    \medspace\ensuremath\mathbf{M}
}
\DeclareMathOperator { \tlletterstrongrelease } {
    \medspace\ensuremath\mathcal{M}
}
\DeclareMathOperator { \tlsymbstrongrelease } {
    \medspace\ensuremath\mathcal{M}
}
\ProvideDocumentCommand { \tlstrongrelease } { O{} } {
    \__temporal_logic_op_sub:cn {
        \int_case:nnF { \g_temporallogic_display_mode_int }
        {
            {\c_temporallogic_display_mode_bold}     { tlboldstrongrelease }
            {\c_temporallogic_display_mode_letter}   { tlletterstrongrelease }
            {\c_temporallogic_display_mode_symbolic} { tlsymbstrongrelease }
        }{}
    } { #1 }
}
\ProvideDocumentCommand { \tlopstrongrelease } { }
{ \negmedspace\tlstrongrelease\! }



```

```
% Mighty Release
\DeclareMathOperator { \tlboldmightyrelease } { \tlboldstrongrelease }
\DeclareMathOperator { \tllettermightyrelease } { \tlletterstrongrelease }
\DeclareMathOperator { \tlsymbmightyrelease } { \tlsymbstrongrelease }
\ProvideDocumentCommand { \tlmightyrelease } { O{} } {
    \__temporal_logic_op_sub:cn {
        \int_case:nnF { \g_temporallogic_display_mode_int }
        {
            {\c_temporallogic_display_mode_bold}     { tlboldmightyrelease }
            {\c_temporallogic_display_mode_letter}   { tllettermightyrelease }
            {\c_temporallogic_display_mode_symbolic} { tlsymbmightyrelease }
        }{}
    } { #1 }
}
\ProvideDocumentCommand { \tlopmightyrelease } { }
{ \negmedspace\tlmightyrelease\! }



% Yesterday
\DeclareMathOperator { \tlboldyesterday } {
    \ensuremath\mathbf{Y}
}
\DeclareMathOperator { \tlletteryesterday } {
    \ensuremath\mathcal{Y}
}
\DeclareMathOperator { \tlsymbyesterday } {
    \__temporal_logic_render_op:n {
        \draw[fill]
        (.5*\EX, .5*\EX)
        circle
        (.4*\EX);
    }
}
\ProvideDocumentCommand { \tlyesterday } { O{} } {
    \__temporal_logic_op_sub:cn {
        \int_case:nnF { \g_temporallogic_display_mode_int }
        {
            {\c_temporallogic_display_mode_bold}     { tlboldyesterday }
            {\c_temporallogic_display_mode_letter}   { tlletteryesterday }
            {\c_temporallogic_display_mode_symbolic} { tlsymbyesterday }
        }{}
    } { #1 }
}
\ProvideDocumentCommand { \tlopyesterday } { } { \tlyesterday\! }



% Previous
\DeclareMathOperator { \tlboldprevious } { \tlboldyesterday }
\DeclareMathOperator { \tlletterprevious } { \tlletteryesterday }
\DeclareMathOperator { \tlsymbprevious } { \tlsymbyesterday }
\ProvideDocumentCommand { \tlprevious } { O{} } {
    \__temporal_logic_op_sub:cn {
```

```
        \int_case:nnF { \g_temporallogic_display_mode_int }
        {
            {\c_temporallogic_display_mode_bold}     { tlboldprevious }
            {\c_temporallogic_display_mode_letter}   { tlletterprevious }
            {\c_temporallogic_display_mode_symbolic} { tlsymbprevious }
        }{}
    } { #1 }
}
\ProvideDocumentCommand { \tloprevious } { } { \tlprevious\! }


% Once
\DeclareMathOperator { \tlboldonce } {
    \ensuremath\mathbf{O}
}
\DeclareMathOperator { \tlletteronce } {
    \ensuremath\mathcal{O}
}
\DeclareMathOperator { \tlsymbonce } {
    \__temporal_logic_render_op:n {
        \draw[fill]
        (.5*\EX, 0) --
        (.2*\EX, .5*\EX) --
        (.5*\EX, \EX) --
        (.8*\EX, .5*\EX) --
        cycle;
    }
}
\ProvideDocumentCommand { \tlonce } { O{} } {
    \__temporal_logic_op_sub:cn {
        \int_case:nnF { \g_temporallogic_display_mode_int }
        {
            {\c_temporallogic_display_mode_bold}     { tlboldonce }
            {\c_temporallogic_display_mode_letter}   { tlletteronce }
            {\c_temporallogic_display_mode_symbolic} { tlsymbonce }
        }{}
    } { #1 }
}
\ProvideDocumentCommand { \tloponce } { } { \tlonce\! }



% Historically
\DeclareMathOperator { \tlboldhistorically } {
    \ensuremath\mathbf{H}
}
\DeclareMathOperator { \tlletterhistorically } {
    \ensuremath\mathcal{H}
}
\DeclareMathOperator { \tlsymbhistorically } {
    \__temporal_logic_render_op:n {
        \draw[fill]
        (.15*\EX, .15*\EX)
        rectangle
```

```
        (.85*\EX, .85*\EX);
    }
}
\ProvideDocumentCommand { \tlhistorically } { O{} } {
    \__temporal_logic_op_sub:cn {
        \int_case:nnF { \g_temporallogic_display_mode_int }
        {
            {\c_temporallogic_display_mode_bold}     { tlboldhistorically }
            {\c_temporallogic_display_mode_letter}   { tlletterhistorically }
            {\c_temporallogic_display_mode_symbolic} { tlsymbhistorically }
        }{}
    } { #1 }
}
\ProvideDocumentCommand { \tlophistorically } { } { \tlhistorically\! }



% Since
\DeclareMathOperator { \tlboldsince } {
    \medspace\ensuremath\mathbf{S}
}
\DeclareMathOperator { \tllettersince } {
    \medspace\ensuremath\mathcal{S}
}
\DeclareMathOperator { \tlsymbsince } {
    \medspace\ensuremath\mathcal{S}
}
\ProvideDocumentCommand { \tlsince } { O{} } {
    \__temporal_logic_op_sub:cn {
        \int_case:nnF { \g_temporallogic_display_mode_int }
        {
            {\c_temporallogic_display_mode_bold}     { tlboldsince }
            {\c_temporallogic_display_mode_letter}   { tllettersince }
            {\c_temporallogic_display_mode_symbolic} { tlsymbsince }
        }{}
    } { #1 }
}
\ProvideDocumentCommand { \tlopsince } { } { \negmedspace\tlsince\!}



% Back to
\DeclareMathOperator { \tlboldbackto } {
    \medspace\ensuremath\mathbf{B}
}
\DeclareMathOperator { \tlletterbackto } {
    \medspace\ensuremath\mathcal{B}
}
\DeclareMathOperator { \tlsymbbackto } {
    \medspace\ensuremath\mathcal{B}
}
\ProvideDocumentCommand { \tlbackto } { O{} } {
    \__temporal_logic_op_sub:cn {
        \int_case:nnF { \g_temporallogic_display_mode_int }
```

```
        {
            {\c_temporallogic_display_mode_bold}     { tlboldbackto }
            {\c_temporallogic_display_mode_letter}   { tlletterbackto }
            {\c_temporallogic_display_mode_symbolic} { tlsymbbackto }
        }{}
    } { #1 }
}
\ProvideDocumentCommand { \tlopbackto } { } { \negmedspace\tlbackto\! }


% Weak Since
\DeclareMathOperator { \tlboldweaksince } {
    \medspace\ensuremath\mathbf{WS}
}
\DeclareMathOperator { \tlletterweaksince } {
    \medspace\ensuremath\mathcal{WS}
}
\DeclareMathOperator { \tlsymbweaksince } {
    \medspace\ensuremath\mathcal{WS}
}
\ProvideDocumentCommand { \tlweaksince } { O{} } {
    \__temporal_logic_op_sub:cn {
        \int_case:nnF { \g_temporallogic_display_mode_int }
        {
            {\c_temporallogic_display_mode_bold}     { tlboldweaksince }
            {\c_temporallogic_display_mode_letter}   { tlletterweaksince }
            {\c_temporallogic_display_mode_symbolic} { tlsymbweaksince }
        }{}
    } { #1 }
}
\ProvideDocumentCommand { \tlopweaksince } { } { \negmedspace\tlweaksince\! }



% Trigger
\DeclareMathOperator { \tlboldtrigger } {
    \medspace\ensuremath\mathbf{T}
}
\DeclareMathOperator { \tllettertrigger } {
    \medspace\ensuremath\mathcal{T}
}
\DeclareMathOperator { \tlsymbtrigger } {
    \medspace\ensuremath\mathcal{T}
}
\ProvideDocumentCommand { \tltrigger } { O{} } {
    \__temporal_logic_op_sub:cn {
        \int_case:nnF { \g_temporallogic_display_mode_int }
        {
            {\c_temporallogic_display_mode_bold}     { tlboldtrigger }
            {\c_temporallogic_display_mode_letter}   { tllettertrigger }
            {\c_temporallogic_display_mode_symbolic} { tlsymbtrigger }
        }{}
    } { #1 }
}
```

```
\ProvideDocumentCommand { \tloptrigger } { } { \negmedspace\tltrigger\! }



% Min-/Max prevalence
\DeclareMathOperator { \tlsymbminprevalence } {
    \__temporal_logic_render_op:n {
        \draw
        (.1*\EX, .9*\EX) --
        (.9*\EX, .9*\EX) --
        (.5*\EX, .1*\EX) --
        cycle;
    }
}
\DeclareMathOperator { \tlsymbpastminprevalence } {
    \__temporal_logic_render_op:n {
        \draw[fill]
        (.1*\EX, .9*\EX) --
        (.9*\EX, .9*\EX) --
        (.5*\EX, .1*\EX) --
        cycle;
    }
}
\DeclareMathOperator { \tlsymbmaxprevalence } {
    \__temporal_logic_render_op:n {
        \draw
        (.1*\EX, .1*\EX) --
        (.9*\EX, .1*\EX) --
        (.5*\EX, .9*\EX) --
        cycle;
    }
}
\DeclareMathOperator { \tlsymbpastmaxprevalence } {
    \__temporal_logic_render_op:n {
        \draw[fill]
        (.1*\EX, .1*\EX) --
        (.9*\EX, .1*\EX) --
        (.5*\EX, .9*\EX) --
        cycle;
    }
}
\ProvideDocumentCommand { \tlminprevalence } { m O{} } {
    \__temporal_logic_op_sup_sub:cnn { tlsymbminprevalence } { #1 } { #2 }
}
\ProvideDocumentCommand { \tlpastminprevalence } { m O{} } {
    \__temporal_logic_op_sup_sub:cnn { tlsymbpastminprevalence } { #1 } { #2 }
}
\ProvideDocumentCommand { \tlmaxprevalence } { m O{} } {
    \__temporal_logic_op_sup_sub:cnn { tlsymbmaxprevalence } { #1 } { #2 }
}
\ProvideDocumentCommand { \tlpastmaxprevalence } { m O{} } {
    \__temporal_logic_op_sup_sub:cnn { tlsymbpastmaxprevalence } { #1 } { #2 }
}
\ProvideDocumentCommand { \tlopminprevalence } { m }
```

```
{ \tlminprevalence{#1}\! }
\ProvideDocumentCommand { \tloppastminprevalence } { m }
{ \tlpastminprevalence{#1}\! }
\ProvideDocumentCommand { \tlopmaxprevalence } { m }
{ \tlmaxprevalence{#1}\! }
\ProvideDocumentCommand { \tloppastmaxprevalence } { m }
{ \tlpastmaxprevalence{#1}\! }



% Bind
\DeclareMathOperator { \tlsymbbind } {
    \__temporal_logic_render_op:n {
        \draw (.5*\EX, \EX) -- (.5*\EX, 0);
        \draw
        (.2*\EX, .3*\EX) ..
        controls (.4*\EX, .2*\EX) ..
        (.5*\EX, 0) ..
        controls (.6*\EX, .2*\EX) ..
        (.8*\EX, .3*\EX);
    }
}
\ProvideDocumentCommand { \tlbind } { m m } {
    \__temporal_logic_op_sup_sub:cnn { tlsymbbind } { #1 } { #2 }
}
\ProvideDocumentCommand { \tlopbind } { m m } { \tlbind{ {#1} }{ {#2} } }



% Rise
\DeclareMathOperator { \tlsymbrise } {
    \__temporal_logic_render_op:n {
        \draw
        (.1*\EX, .1*\EX) --
        (.9*\EX, .9*\EX);
        \draw
        (.4*\EX, .9*\EX) --
        (.9*\EX, .9*\EX) --
        (.9*\EX, .4*\EX);
    }
}
\ProvideDocumentCommand { \tlrise } { O{} } {
    \__temporal_logic_op_sub:cn { tlsymbrise } { #1 }
}
\ProvideDocumentCommand { \tloprise } { } { \tlrise\! }



% Fall
\DeclareMathOperator { \tlsymbfall } {
    \__temporal_logic_render_op:n {
        \draw
        (.1*\EX, .9*\EX) --
        (.9*\EX, .1*\EX);
```

```
        \draw
        (.4*\EX, .1*\EX) --
        (.9*\EX, .1*\EX) --
        (.9*\EX, .6*\EX);
    }
}
\ProvideDocumentCommand { \tlfall } { O{} } {
    \__temporal_logic_op_sub:cn { tlsymbfall } { #1 }
}
\ProvideDocumentCommand { \tlopfall } { } { \tlfall\! }


% Prophecy
\DeclareMathOperator { \tlsymbprophecy } {
    \__temporal_logic_render_op:n {
        \draw
        (.1*\EX, .1*\EX) --
        (.1*\EX, .9*\EX) --
        (.9*\EX, .5*\EX) --
        cycle;
    }
}
\ProvideDocumentCommand { \tlprophecy } { O{} } {
    \__temporal_logic_op_sub:cn { tlsymbprophecy } { #1 }
}
\ProvideDocumentCommand { \tlopprophecy } { } { \tlprophecy\! }



% History
\DeclareMathOperator { \tlsymbhistory } {
    \__temporal_logic_render_op:n {
        \draw
        (.9*\EX, .1*\EX) --
        (.9*\EX, .9*\EX) --
        (.1*\EX, .5*\EX) --
        cycle;
    }
}
\ProvideDocumentCommand { \tlhistory } { O{} } {
    \__temporal_logic_op_sub:cn { tlsymbhistory } { #1 }
}
\ProvideDocumentCommand { \tlophistory } { } { \tlhistory\! }
\ExplSyntaxOff
% </package>
```