

temporal-logic

Dominik Schmid

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.

¹Pnueli, 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>.

²Alur, 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>.

³Basin, 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>.

⁴Schallau, 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.

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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 L^AT_EX 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:

<code>displaymode=bold</code>	Bold display mode
<code>displaymode=caligraphic</code>	Caligraphic display mode
<code>displaymode=symbol</code>	Symbol display mode (default)

For brevity, `displaymode=` can be omitted.

The superscripts and subscripts are automatically captured by `mathrm` / `mathit`. To switch between roman and italic display, the `scriptmode` can be passed:

<code>scriptmode=roman</code>	Roman script mode (default)
<code>scriptmode=italic</code>	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.

<code>\tlnext</code>	<code>\tlnext \varphi</code>
<code>\tlfinally</code>	<code>\tlfinally \varphi</code>
<code>\tleventually</code>	<code>\tleventually \varphi</code>
<code>\tlglobally</code>	<code>\tlglobally \varphi</code>
<code>\tluntil</code>	<code>\varphi \tluntil \psi</code>
<code>\tlrelease</code>	<code>\psi \tlrelease \varphi</code>
<code>\tlweakuntil</code>	<code>\varphi \tlweakuntil \psi</code>
<code>\tlstrongrelease</code>	<code>\psi \tlstrongrelease \varphi</code>
<code>\tlmightyrelease</code>	<code>\psi \tlmightyrelease \varphi</code>

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
<code>\tlnext</code>	$\mathbf{X}\varphi$	$\mathcal{X}\varphi$	$\bigcirc\varphi$	φ must hold at the next state.
<code>\tlfinally</code> <code>\tleventually</code>	$\mathbf{F}\varphi$	$\mathcal{F}\varphi$	$\diamond\varphi$	φ must hold at least once in the future.
<code>\tlglobally</code>	$\mathbf{G}\varphi$	$\mathcal{G}\varphi$	$\square\varphi$	φ must hold from now for the entire trace.
<code>\tluntil</code>	$\varphi \mathbf{U}\psi$	$\varphi \mathcal{U}\psi$	$\varphi \mathcal{U}\psi$	φ must hold at least until ψ holds, which must hold at the current or a future position.
<code>\tlrelease</code>	$\psi \mathbf{R}\varphi$	$\psi \mathcal{R}\varphi$	$\psi \mathcal{R}\varphi$	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.
<code>\tlweakuntil</code>	$\varphi \mathbf{W}\psi$	$\varphi \mathcal{W}\psi$	$\varphi \mathcal{W}\psi$	φ must hold at least until ψ holds. If ψ never becomes true, φ must remain true for the entire trace.
<code>\tlstrongrelease</code> <code>\tlmightyrelease</code>	$\psi \mathbf{M}\varphi$	$\psi \mathcal{M}\varphi$	$\psi \mathcal{M}\varphi$	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.

<code>\tlyesterday</code>	<code>\tlyesterday \varphi</code>
<code>\tlprevious</code>	<code>\tlprevious \varphi</code>
<code>\tlonce</code>	<code>\tlonce \varphi</code>
<code>\tlhistorically</code>	<code>\tlhistorically \varphi</code>
<code>\tlsince</code>	<code>\varphi \tlsince \psi</code>
<code>\tlbackto</code>	<code>\psi \tlbackto \varphi</code>
<code>\tlweaksince</code>	<code>\varphi \tlweaksince \psi</code>
<code>\tltrigger</code>	<code>\psi \tltrigger \varphi</code>

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

<code>\tlnext</code>	<code>\tlnext[⟨Interval⟩]</code>	$\circ_{[0,1]}$
<code>\tlfinally</code>	<code>\tlfinally[⟨Interval⟩]</code>	$\diamond_{[0,1]}$
<code>\tleventually</code>	<code>\tleventually[⟨Interval⟩]</code>	$\diamond_{[0,1]}$
<code>\tlglobally</code>	<code>\tlglobally[⟨Interval⟩]</code>	$\square_{[0,1]}$
<code>\tluntil</code>	<code>\tluntil[⟨Interval⟩]</code>	$\mathcal{U}_{[0,1]}$
<code>\tlrelease</code>	<code>\tlrelease[⟨Interval⟩]</code>	$\mathcal{R}_{[0,1]}$
<code>\tlweakuntil</code>	<code>\tlweakuntil[⟨Interval⟩]</code>	$\mathcal{W}_{[0,1]}$
<code>\tlstrongrelease</code>	<code>\tlstrongrelease[⟨Interval⟩]</code>	$\mathcal{M}_{[0,1]}$
<code>\tlmightyrelease</code>	<code>\tlmightyrelease[⟨Interval⟩]</code>	$\mathcal{M}_{[0,1]}$
<code>\tlyesterday</code>	<code>\tlyesterday[⟨Interval⟩]</code>	$\bullet_{[0,1]}$
<code>\tlprevious</code>	<code>\tlprevious[⟨Interval⟩]</code>	$\bullet_{[0,1]}$
<code>\tlonce</code>	<code>\tlonce[⟨Interval⟩]</code>	$\blacklozenge_{[0,1]}$
<code>\tlhistorically</code>	<code>\tlhistorically[⟨Interval⟩]</code>	$\blacksquare_{[0,1]}$
<code>\tlsince</code>	<code>\tlsince[⟨Interval⟩]</code>	$\mathcal{S}_{[0,1]}$
<code>\tlbackto</code>	<code>\tlbackto[⟨Interval⟩]</code>	$\mathcal{B}_{[0,1]}$
<code>\tlweaksince</code>	<code>\tlweaksince[⟨Interval⟩]</code>	$\mathcal{WS}_{[0,1]}$
<code>\tltrigger</code>	<code>\tltrigger[⟨Interval⟩]</code>	$\mathcal{T}_{[0,1]}$

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, \infty)}]` $\implies \circ_{[0, \infty)}$.

2.4 MFOTL extension

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

<code>\exists</code>	<code>\exists</code>	\exists
<code>\forall</code>	<code>\forall</code>	\forall

2.5 CMFTBL extension

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

<code>\tlminprevalence</code>	<code>\tlminprevalence{⟨Percentage⟩}[⟨Interval⟩]</code>	$\nabla_{[0,1]}^{0.8}$
<code>\tlpastminprevalence</code>	<code>\tlpastminprevalence{⟨Percentage⟩}[⟨Interval⟩]</code>	$\blacktriangledown_{[0,1]}^{0.8}$
<code>\tlmaxprevalence</code>	<code>\tlmaxprevalence{⟨Percentage⟩}[⟨Interval⟩]</code>	$\Delta_{[0,1]}^{0.8}$
<code>\tlpastmaxprevalence</code>	<code>\tlpastmaxprevalence{⟨Percentage⟩}[⟨Interval⟩]</code>	$\blacktriangle_{[0,1]}^{0.8}$
<code>\tlbind</code>	<code>\tlbind{⟨Valuation⟩}{⟨Variable⟩}</code>	$\downarrow_i^{v.id}$

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
<code>\tlminprevalence</code>	$\nabla_I^p \varphi$	φ must hold in at least fraction p of the future states in the interval I .
<code>\tlpastminprevalence</code>	$\blacktriangledown_I^p \varphi$	φ must have held in at least fraction p of the past states in the interval I .
<code>\tlmaxprevalence</code>	$\Delta_I^p \varphi$	φ must hold in at most fraction p of the future states in the interval I .
<code>\tlpastmaxprevalence</code>	$\blacktriangle_I^p \varphi$	φ must have held in at most fraction p of the past states in the interval I .
<code>\tlbind</code>	$\downarrow_i^{v.id}$	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:

<code>\tlrise</code>	<code>\tlrise \varphi</code>
<code>\tlfall</code>	<code>\tlfall \varphi</code>
<code>\tlprophecy</code>	<code>\tlprophecy \varphi</code>
<code>\tlhistory</code>	<code>\tlhistory \varphi</code>

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

<code>\tleventually\varphi</code>	$\diamond \varphi$
<code>\tlglobally[[0,1]]\varphi</code>	$\square_{[0,1]} \varphi$

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

<code>\varphi\rtluntil\psi</code>	$\varphi \mathcal{U} \psi$
<code>\varphi\rtluntil[[0,1]]\psi</code>	$\varphi \mathcal{U}_{[0,1]} \psi$

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

<code>\tlminprevalence{0.8}\varphi</code>	$\nabla^{0.8} \varphi$
<code>\tlpastmaxprevalence{0.8}[[0,1]]\varphi</code>	$\Delta_{[0,1]}^{0.8} \varphi$
<code>\tlbind{v.id}{i}\varphi</code>	$\downarrow_i^{v.id} \varphi$

4 Standalone symbols

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

<code>\tlopNext</code>	<code>\tlopNext</code>	\circ
<code>\tlopfinally</code>	<code>\tlopfinally</code>	\diamond
<code>\tlopeventually</code>	<code>\tlopeventually</code>	\diamond
<code>\tlopglobally</code>	<code>\tlopglobally</code>	\square
<code>\tlopuntil</code>	<code>\tlopuntil</code>	\mathcal{U}
<code>\tloprelease</code>	<code>\tloprelease</code>	\mathcal{R}
<code>\tlopweakuntil</code>	<code>\tlopweakuntil</code>	\mathcal{W}
<code>\tlopstrongrelease</code>	<code>\tlopstrongrelease</code>	\mathcal{M}
<code>\tlopmightyrelease</code>	<code>\tlopmightyrelease</code>	\mathcal{M}
<code>\tlyesterday</code>	<code>\tlopyesterday</code>	\bullet
<code>\tlprevious</code>	<code>\tlopprevious</code>	\bullet
<code>\tlonce</code>	<code>\tloponce</code>	\blacklozenge
<code>\tlhistorically</code>	<code>\tlophistorically</code>	\blacksquare
<code>\tlsince</code>	<code>\tlopsince</code>	\mathcal{S}
<code>\tlbackto</code>	<code>\tlopbackto</code>	\mathcal{B}
<code>\tlweaksince</code>	<code>\tlopweaksince</code>	\mathcal{WS}
<code>\tltrigger</code>	<code>\tloptrigger</code>	\mathcal{T}
<code>\tlopinprevalence</code>	<code>\tlopinprevalence{}</code>	∇
<code>\tloppastminprevalence</code>	<code>\tloppastminprevalence{}</code>	\blacktriangledown
<code>\tlopmaxprevalence</code>	<code>\tlopmaxprevalence{}</code>	\triangle
<code>\tloppastmaxprevalence</code>	<code>\tloppastmaxprevalence{}</code>	\blacktriangle
<code>\tlopbind</code>	<code>\tlopbind{}{}</code>	\downarrow
<code>\tloprise</code>	<code>\tloprise</code>	\nearrow
<code>\tlopfall</code>	<code>\tlopfall</code>	\searrow
<code>\tlopprophecy</code>	<code>\tlopprophecy</code>	\triangleright
<code>\tlophistory</code>	<code>\tlophistory</code>	\triangleleft

5 Dependencies

The package loads the following dependencies:

- *expl3* For L^AT_EX3 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

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Dominik Schmid

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and version 1.3c or later is part of all distributions of L^AT_EX version 2005/12/01 or later.

This work has the LPPL maintenance status "maintained".

The current maintainer of this work is
Dominik Schmid <dominik.schmid@tu-dortmund.de>.

This work consists of the files temporal-logic.dtx, temporal-logic.ins,
and the derived file temporal-logic.sty.

7 Sourcecode

```
1 % <*package>
2
3 \ProvidesExplPackage
4 {temporal-logic}
5 { 2026-01-06 }
6 { v1.1 }
7 { Symbols for Temporal Logics }
8
9 \RequirePackage{expl3}
10 \RequirePackage{l3keys2e}
11 \RequirePackage{xparse}
12 \RequirePackage{amsmath}
13 \RequirePackage{tikz}
14
15 \ExplSyntaxOn
16
17 \msg_new:nnn { temporallogic } { multiple-display-modes }
18 { Multiple-display-mode-options-given;~using-the-last-one. }
19
20 \msg_new:nnn { temporallogic } { multiple-script-modes }
21 { Multiple-script-mode-options-given;~using-the-last-one. }
22
23 \int_new:N \g_temporallogic_display_mode_int
24 \int_new:N \g_temporallogic_script_mode_int
25 \int_new:N \g_temporallogic_display_mode_count_int
26 \int_new:N \g_temporallogic_script_mode_count_int
27 \int_const:Nn \c_temporallogic_display_mode_bold { 1 }
28 \int_const:Nn \c_temporallogic_display_mode_letter { 2 }
29 \int_const:Nn \c_temporallogic_display_mode_symbolic { 3 }
30 \int_const:Nn \c_temporallogic_script_mode_roman { 1 }
31 \int_const:Nn \c_temporallogic_script_mode_italic { 2 }
32
33 \keys_define:nn { temporallogic }
34 {
35   displaymode .choice:,
36
37   displaymode / bold .code:n =
38   {
39     \int_gset:Nn \g_temporallogic_display_mode_int
40     { \c_temporallogic_display_mode_bold }
41     \int_gincr:N \g_temporallogic_display_mode_count_int
42   },
43
44   displaymode / letter .code:n =
45   {
46     \int_gset:Nn \g_temporallogic_display_mode_int
47     { \c_temporallogic_display_mode_letter }
48     \int_gincr:N \g_temporallogic_display_mode_count_int
49   },
50
51   displaymode / symbolic .code:n =
52   {
```

```

53     \int_gset:Nn \g_temporallogic_display_mode_int
54     { \c_temporallogic_display_mode_symbolic }
55     \int_gincr:N \g_temporallogic_display_mode_count_int
56 },
57
58 % default
59 displaymode .initial:n = symbolic,
60
61 % short forms
62 bold .meta:n = { displaymode = bold },
63 letter .meta:n = { displaymode = letter },
64 symbolic .meta:n = { displaymode = symbolic },
65
66 scriptmode .choice:,
67 scriptmode / roman .code:n =
68 {
69     \int_gset:Nn \g_temporallogic_script_mode_int
70     { \c_temporallogic_script_mode_roman }
71     \int_gincr:N \g_temporallogic_script_mode_count_int
72 },
73 scriptmode / italic .code:n =
74 {
75     \int_gset:Nn \g_temporallogic_script_mode_int
76     { \c_temporallogic_script_mode_italic }
77     \int_gincr:N \g_temporallogic_script_mode_count_int
78 },
79 scriptmode .initial:n = roman,
80
81 % short forms
82 roman .meta:n = { scriptmode = roman },
83 italic .meta:n = { scriptmode = italic },
84 }
85
86 \ProcessKeysOptions { temporallogic }
87
88 \int_compare:nNnT { \g_temporallogic_display_mode_count_int } > { 2 }
89 {
90     \msg_warning:nn { temporallogic } { multiple-display-modes }
91 }
92
93 \int_compare:nNnT { \g_temporallogic_script_mode_count_int } > { 2 }
94 {
95     \msg_warning:nn { temporallogic } { multiple-script-modes }
96 }
97
98
99
100 \cs_new:Nn \__temporal_logic_op_sup_sub:Nnn {
101     \ensuremath {
102         #1
103         \int_case:nnF { \g_temporallogic_script_mode_int }
104         {
105             {
106                 \c_temporallogic_script_mode_roman} {

```

```

107         \tl_if_empty:nF { #2 } { \c_math_superscript_token
108             { \,\mathrm{#2} } }
109         \tl_if_empty:nF { #3 } { \c_math_subscript_token
110             { \,\mathrm{#3} } }
111     }
112     {
113         \c_temporallogic_script_mode_italic} {
114         \tl_if_empty:nF { #2 } { \c_math_superscript_token
115             { \,\mathit{#2} } }
116         \tl_if_empty:nF { #3 } { \c_math_subscript_token
117             { \,\mathit{#3} } }
118     }
119     }{}
120     \,
121 }
122 }
123 \cs_generate_variant:Nn \__temporal_logic_op_sup_sub:Nnn { cnn }
124
125 \cs_new:Nn \__temporal_logic_op_sup:Nn
126 { \__temporal_logic_op_sup_sub:Nnn { #1 } { #2 } {} }
127 \cs_generate_variant:Nn \__temporal_logic_op_sup:Nn { cn }
128
129 \cs_new:Nn \__temporal_logic_op_sub:Nn
130 { \__temporal_logic_op_sup_sub:Nnn { #1 } {} { #2 } }
131 \cs_generate_variant:Nn \__temporal_logic_op_sub:Nn { cn }
132
133 \cs_new:Nn \__temporal_logic_op:N
134 { \__temporal_logic_op_sup_sub:Nnn { #1 } {} {} }
135 \cs_generate_variant:Nn \__temporal_logic_op:N { c }
136
137 \dim_new:N \__temporal_logic_fht_dim
138 \cs_new:Nn \__temporal_logic_ex: { \dim_use:N \__temporal_logic_fht_dim }
139
140 \cs_new:Nn \__temporal_logic_render_op:n {
141     \dim_set:Nn \__temporal_logic_fht_dim {\fontcharht\font{X}}
142     \tikz[execute-at-end~picture={
143         \useasboundingbox (0, 0)
144         rectangle
145         (\__temporal_logic_ex:, \__temporal_logic_ex:);
146     }]{
147     \group_begin:
148     \cs_set_eq:NN \EX \__temporal_logic_ex:
149     #1
150     \group_end:
151 }
152 }
153
154
155
156 \ProvideDocumentCommand \tldisplaymode {} {
157     \int_case:nnF { \g_temporallogic_display_mode_int }
158     {
159         {\c_temporallogic_display_mode_bold} { Bold }
160         {\c_temporallogic_display_mode_letter} { Letter }

```

```

161         {\c_temporallogic_display_mode_symbolic} { Symbolic }
162     }{}
163 }
164 \ProvideDocumentCommand \tlscriptmode {} {
165     \int_case:nnF { \g_temporallogic_script_mode_int }
166     {
167         {\c_temporallogic_script_mode_roman} { Roman }
168         {\c_temporallogic_script_mode_italic} { Italic }
169     }{}
170 }
171
172
173
174 % Next
175 \DeclareMathOperator { \tlboldnext } {
176     \ensuremath{\mathbf{X}}
177 }
178 \DeclareMathOperator { \tlletternext } {
179     \ensuremath{\mathcal{X}}
180 }
181 \DeclareMathOperator { \tlsymbnext } {
182     \__temporal_logic_render_op:n {
183         \draw
184         (.5*\EX, .5*\EX)
185         circle
186         (.4*\EX);
187     }
188 }
189 \ProvideDocumentCommand { \tlnext } { 0{} } {
190     \__temporal_logic_op_sub:cn {
191         \int_case:nnF { \g_temporallogic_display_mode_int }
192         {
193             {\c_temporallogic_display_mode_bold}      { \tlboldnext }
194             {\c_temporallogic_display_mode_letter}    { \tlletternext }
195             {\c_temporallogic_display_mode_symbolic}  { \tlsymbnext }
196         }{}
197     } { #1 }
198 }
199 \ProvideDocumentCommand { \tlopnext } { } { \tlnext\! }
200
201
202
203 % Finally
204 \DeclareMathOperator { \tlboldfinally } {
205     \ensuremath{\mathbf{F}}
206 }
207 \DeclareMathOperator { \tlletterfinally } {
208     \ensuremath{\mathcal{F}}
209 }
210 \DeclareMathOperator { \tlsymbfinally } {
211     \__temporal_logic_render_op:n {
212         \draw
213         (.5*\EX, 0) --
214         (.2*\EX, .5*\EX) --

```

```

215     (.5*\EX, \EX) --
216     (.8*\EX, .5*\EX) --
217     cycle;
218 }
219 }
220 \ProvideDocumentCommand { \tlfinally } { 0{ } } {
221   \__temporal_logic_op_sub:cn {
222     \int_case:nnF { \g_temporallogic_display_mode_int }
223     {
224       {\c_temporallogic_display_mode_bold}      { tlbolddfinally }
225       {\c_temporallogic_display_mode_letter}    { tlletterfinally }
226       {\c_temporallogic_display_mode_symbolic}  { tlsymbfinally }
227     }{}
228   } { #1 }
229 }
230 \ProvideDocumentCommand { \tlopfinally } { } { \tlfinally\! }
231
232
233
234 % Eventually
235 \DeclareMathOperator { \tlboldeventually } { \tlbolddfinally }
236 \DeclareMathOperator { \tllettereventually } { \tlletterfinally }
237 \DeclareMathOperator { \tlsymbeventually } { \tlsymbfinally }
238 \ProvideDocumentCommand { \tleventually } { 0{ } } {
239   \__temporal_logic_op_sub:cn {
240     \int_case:nnF { \g_temporallogic_display_mode_int }
241     {
242       {\c_temporallogic_display_mode_bold}      { tlboldeventually }
243       {\c_temporallogic_display_mode_letter}    { tllettereventually }
244       {\c_temporallogic_display_mode_symbolic}  { tlsymbeventually }
245     }{}
246   } { #1 }
247 }
248 \ProvideDocumentCommand { \tlopeventually } { } { \tleventually\! }
249
250
251 % Globally
252 \DeclareMathOperator { \tlboldglobally } {
253   \ensuremath\mathbf{G}
254 }
255 \DeclareMathOperator { \tlletterglobally } {
256   \ensuremath\mathcal{G}
257 }
258 \DeclareMathOperator { \tlsymbglobally } {
259   \__temporal_logic_render_op:n {
260     \draw
261     (.15*\EX, .15*\EX)
262     rectangle
263     (.85*\EX, .85*\EX);
264   }
265 }
266 \ProvideDocumentCommand { \tlglobally } { 0{ } } {
267   \__temporal_logic_op_sub:cn {
268     \int_case:nnF { \g_temporallogic_display_mode_int }

```

```

269     {
270         {\c_temporallogic_display_mode_bold}      { tlbolddglobally }
271         {\c_temporallogic_display_mode_letter}    { tlletterglobally }
272         {\c_temporallogic_display_mode_symbolic}  { tlsymbglobally }
273     }{}
274 } { #1 }
275 }
276 \ProvideDocumentCommand { \tloglobally } { } { \tlglobally\! }
277
278
279
280 % Until
281 \DeclareMathOperator { \tlbolduntil } {
282     \medspace\ensuremath\mathbf{U}
283 }
284 \DeclareMathOperator { \tlletteruntil } {
285     \medspace\ensuremath\mathcal{U}
286 }
287 \DeclareMathOperator { \tlsymbuntil } {
288     \medspace\ensuremath\mathcal{U}
289 }
290 \ProvideDocumentCommand { \tluntil } { 0{} } {
291     \_temporal_logic_op_sub:cn {
292         \int_case:nnF { \g_temporallogic_display_mode_int }
293         {
294             {\c_temporallogic_display_mode_bold}      { tlbolduntil }
295             {\c_temporallogic_display_mode_letter}    { tlletteruntil }
296             {\c_temporallogic_display_mode_symbolic}  { tlysymbuntil }
297         }{}
298     } { #1 }
299 }
300 \ProvideDocumentCommand { \tlopuntil } { } { \negmedspace\tluntil\! }
301
302
303
304 % Release
305 \DeclareMathOperator { \tlboldrelease } {
306     \medspace\ensuremath\mathbf{R}
307 }
308 \DeclareMathOperator { \tlletterrelease } {
309     \medspace\ensuremath\mathcal{R}
310 }
311 \DeclareMathOperator { \tlsymbrelease } {
312     \medspace\ensuremath\mathcal{R}
313 }
314 \ProvideDocumentCommand { \tlrelease } { 0{} } {
315     \_temporal_logic_op_sub:cn {
316         \int_case:nnF { \g_temporallogic_display_mode_int }
317         {
318             {\c_temporallogic_display_mode_bold}      { tlboldrelease }
319             {\c_temporallogic_display_mode_letter}    { tlletterrelease }
320             {\c_temporallogic_display_mode_symbolic}  { tlysymbrelease }
321         }{}
322     } { #1 }

```



```

323 }
324 \ProvideDocumentCommand { \tloprelease } { } { \negmedspace\tlrelease\! }
325
326
327
328 % Weak until
329 \DeclareMathOperator { \tlboldweakuntil } {
330   \medspace\ensuremath{\mathbf{W}}
331 }
332 \DeclareMathOperator { \tlletterweakuntil } {
333   \medspace\ensuremath{\mathcal{W}}
334 }
335 \DeclareMathOperator { \tlsymbweakuntil } {
336   \medspace\ensuremath{\mathcal{W}}
337 }
338 \ProvideDocumentCommand { \tlweakuntil } { 0{ } } {
339   \_temporal_logic_op_sub:cn {
340     \int_case:nnF { \g_temporallogic_display_mode_int }
341     {
342       {\c_temporallogic_display_mode_bold}      { tlboldweakuntil }
343       {\c_temporallogic_display_mode_letter}    { tlletterweakuntil }
344       {\c_temporallogic_display_mode_symbolic}  { tlsymbweakuntil }
345     }{}
346   } { #1 }
347 }
348 \ProvideDocumentCommand { \tlopreweakuntil } { } { \negmedspace\tlweakuntil\! }
349
350
351
352 % Strong Release
353 \DeclareMathOperator { \tlboldstrongrelease } {
354   \medspace\ensuremath{\mathbf{M}}
355 }
356 \DeclareMathOperator { \tlletterstrongrelease } {
357   \medspace\ensuremath{\mathcal{M}}
358 }
359 \DeclareMathOperator { \tlsymbstrongrelease } {
360   \medspace\ensuremath{\mathcal{M}}
361 }
362 \ProvideDocumentCommand { \tlstrongrelease } { 0{ } } {
363   \_temporal_logic_op_sub:cn {
364     \int_case:nnF { \g_temporallogic_display_mode_int }
365     {
366       {\c_temporallogic_display_mode_bold}      { tlboldstrongrelease }
367       {\c_temporallogic_display_mode_letter}    { tlletterstrongrelease }
368       {\c_temporallogic_display_mode_symbolic}  { tlsymbstrongrelease }
369     }{}
370   } { #1 }
371 }
372 \ProvideDocumentCommand { \tloprestrongrelease } { }
373 { \negmedspace\tlstrongrelease\! }
374
375
376

```

```

377 % Mighty Release
378 \DeclareMathOperator { \tlboldmightyrelease } { \tlboldstrongrelease }
379 \DeclareMathOperator { \tllettermightyrelease } { \tlletterstrongrelease }
380 \DeclareMathOperator { \tlsymbmightyrelease } { \tlsymbstrongrelease }
381 \ProvideDocumentCommand { \tlmightyrelease } { 0{ } } {
382   \__temporal_logic_op_sub:cn {
383     \int_case:nnF { \g_temporallogic_display_mode_int }
384     {
385       {\c_temporallogic_display_mode_bold}      { tlboldmightyrelease }
386       {\c_temporallogic_display_mode_letter}    { tllettermightyrelease }
387       {\c_temporallogic_display_mode_symbolic}  { tlsymbmightyrelease }
388     }{-}
389   } { #1 }
390 }
391 \ProvideDocumentCommand { \tlopmightyrelease } { }
392 { \negmedspace\tlmightyrelease\! }
393
394
395
396 % Yesterday
397 \DeclareMathOperator { \tlboldyesterday } {
398   \ensuremath\mathbf{Y}
399 }
400 \DeclareMathOperator { \tlletteryesterday } {
401   \ensuremath\mathcal{Y}
402 }
403 \DeclareMathOperator { \tlsymbyesterday } {
404   \__temporal_logic_render_op:n {
405     \draw[fill]
406     (.5*\EX, .5*\EX)
407     circle
408     (.4*\EX);
409   }
410 }
411 \ProvideDocumentCommand { \tlyesterday } { 0{ } } {
412   \__temporal_logic_op_sub:cn {
413     \int_case:nnF { \g_temporallogic_display_mode_int }
414     {
415       {\c_temporallogic_display_mode_bold}      { tlboldyesterday }
416       {\c_temporallogic_display_mode_letter}    { tlletteryesterday }
417       {\c_temporallogic_display_mode_symbolic}  { tlsymbyesterday }
418     }{-}
419   } { #1 }
420 }
421 \ProvideDocumentCommand { \tlopyesterday } { } { \tlyesterday\! }
422
423
424
425 % Previous
426 \DeclareMathOperator { \tlboldprevious } { \tlboldyesterday }
427 \DeclareMathOperator { \tlletterprevious } { \tlletteryesterday }
428 \DeclareMathOperator { \tlsymbprevious } { \tlsymbyesterday }
429 \ProvideDocumentCommand { \tlprevious } { 0{ } } {
430   \__temporal_logic_op_sub:cn {

```

```

431     \int_case:nnF { \g_temporallogic_display_mode_int }
432     {
433         {\c_temporallogic_display_mode_bold}      { tlboldprevious }
434         {\c_temporallogic_display_mode_letter}    { tlletterprevious }
435         {\c_temporallogic_display_mode_symbolic}  { tlsymbprevious }
436     }{}
437 } { #1 }
438 }
439 \ProvideDocumentCommand { \tlopprevious } { } { \tlprevious\! }
440
441
442 % Once
443 \DeclareMathOperator { \tlboldonce } {
444     \ensuremath{\mathbf{0}}
445 }
446 \DeclareMathOperator { \tlletteronce } {
447     \ensuremath{\mathcal{0}}
448 }
449 \DeclareMathOperator { \tlsymbonce } {
450     \_temporal_logic_render_op:n {
451         \draw[fill]
452         (.5*\EX, 0) --
453         (.2*\EX, .5*\EX) --
454         (.5*\EX, \EX) --
455         (.8*\EX, .5*\EX) --
456         cycle;
457     }
458 }
459 \ProvideDocumentCommand { \tlonce } { 0{} } {
460     \_temporal_logic_op_sub:cn {
461         \int_case:nnF { \g_temporallogic_display_mode_int }
462         {
463             {\c_temporallogic_display_mode_bold}      { tlboldonce }
464             {\c_temporallogic_display_mode_letter}    { tlletteronce }
465             {\c_temporallogic_display_mode_symbolic}  { tlysymbonce }
466         }{}
467     } { #1 }
468 }
469 \ProvideDocumentCommand { \tloponce } { } { \tlonce\! }
470
471
472
473 % Historically
474 \DeclareMathOperator { \tlboldhistorically } {
475     \ensuremath{\mathbf{H}}
476 }
477 \DeclareMathOperator { \tlletterhistorically } {
478     \ensuremath{\mathcal{H}}
479 }
480 \DeclareMathOperator { \tlsymbhistorically } {
481     \_temporal_logic_render_op:n {
482         \draw[fill]
483         (.15*\EX, .15*\EX)
484         rectangle

```

```

485     (.85*\EX, .85*\EX);
486   }
487 }
488 \ProvideDocumentCommand { \tlhistorically } { 0{} } {
489   \__temporal_logic_op_sub:cn {
490     \int_case:nnF { \g_temporallogic_display_mode_int }
491     {
492       {\c_temporallogic_display_mode_bold}      { tlboldhistorically }
493       {\c_temporallogic_display_mode_letter}    { tlletterhistorically }
494       {\c_temporallogic_display_mode_symbolic}  { tlsymbhistorically }
495     }{}
496   } { #1 }
497 }
498 \ProvideDocumentCommand { \tlophistorically } { } { \tlhistorically\! }
499
500
501
502 % Since
503 \DeclareMathOperator { \tlboldsince } {
504   \medspace\ensuremath\mathbf{S}
505 }
506 \DeclareMathOperator { \tllettersince } {
507   \medspace\ensuremath\mathcal{S}
508 }
509 \DeclareMathOperator { \tlsymsince } {
510   \medspace\ensuremath\mathcal{S}
511 }
512 \ProvideDocumentCommand { \tlsince } { 0{} } {
513   \__temporal_logic_op_sub:cn {
514     \int_case:nnF { \g_temporallogic_display_mode_int }
515     {
516       {\c_temporallogic_display_mode_bold}      { tlboldsince }
517       {\c_temporallogic_display_mode_letter}    { tllettersince }
518       {\c_temporallogic_display_mode_symbolic}  { tlysymsince }
519     }{}
520   } { #1 }
521 }
522 \ProvideDocumentCommand { \tlopsince } { } { \negmedspace\tlsince\!}
523
524
525
526 % Back to
527 \DeclareMathOperator { \tlboldbackto } {
528   \medspace\ensuremath\mathbf{B}
529 }
530 \DeclareMathOperator { \tlletterbackto } {
531   \medspace\ensuremath\mathcal{B}
532 }
533 \DeclareMathOperator { \tlsymbbackto } {
534   \medspace\ensuremath\mathcal{B}
535 }
536 \ProvideDocumentCommand { \tlbackto } { 0{} } {
537   \__temporal_logic_op_sub:cn {
538     \int_case:nnF { \g_temporallogic_display_mode_int }

```

```

539     {
540         {\c_temporallogic_display_mode_bold}      { tlboldbackto }
541         {\c_temporallogic_display_mode_letter}    { tlletterbackto }
542         {\c_temporallogic_display_mode_symbolic}  { tlsymbbackto }
543     }{}
544 } { #1 }
545 }
546 \ProvideDocumentCommand { \tlopbackto } { } { \negmedspace\tlbackto\! }
547
548
549 % Weak Since
550 \DeclareMathOperator { \tlboldweaksince } {
551     \medspace\ensuremath\mathbf{WS}
552 }
553 \DeclareMathOperator { \tlletterweaksince } {
554     \medspace\ensuremath\mathcal{WS}
555 }
556 \DeclareMathOperator { \tlsymbweaksince } {
557     \medspace\ensuremath\mathcal{WS}
558 }
559 \ProvideDocumentCommand { \tlweaksince } { 0{} } {
560     \_temporal_logic_op_sub:cn {
561         \int_case:nnF { \g_temporallogic_display_mode_int }
562         {
563             {\c_temporallogic_display_mode_bold}      { tlboldweaksince }
564             {\c_temporallogic_display_mode_letter}    { tlletterweaksince }
565             {\c_temporallogic_display_mode_symbolic}  { tlsymbweaksince }
566         }{}
567     } { #1 }
568 }
569 \ProvideDocumentCommand { \tlopweaksince } { } { \negmedspace\tlweaksince\! }
570
571
572
573 % Trigger
574 \DeclareMathOperator { \tlboldtrigger } {
575     \medspace\ensuremath\mathbf{T}
576 }
577 \DeclareMathOperator { \tllettertrigger } {
578     \medspace\ensuremath\mathcal{T}
579 }
580 \DeclareMathOperator { \tlsymbtrigger } {
581     \medspace\ensuremath\mathcal{T}
582 }
583 \ProvideDocumentCommand { \tltrigger } { 0{} } {
584     \_temporal_logic_op_sub:cn {
585         \int_case:nnF { \g_temporallogic_display_mode_int }
586         {
587             {\c_temporallogic_display_mode_bold}      { tlboldtrigger }
588             {\c_temporallogic_display_mode_letter}    { tllettertrigger }
589             {\c_temporallogic_display_mode_symbolic}  { tlysymbtrigger }
590         }{}
591     } { #1 }
592 }

```

```

593 \ProvideDocumentCommand { \tloptrigger } { } { \negmedspace\tltrigger\! }
594
595
596
597 % Min-/Max prevalence
598 \DeclareMathOperator { \tlsymbminprevalence } {
599   \_temporal_logic_render_op:n {
600     \draw
601       (.1*\EX, .9*\EX) --
602       (.9*\EX, .9*\EX) --
603       (.5*\EX, .1*\EX) --
604     cycle;
605   }
606 }
607 \DeclareMathOperator { \tlsymbpastminprevalence } {
608   \_temporal_logic_render_op:n {
609     \draw[fill]
610       (.1*\EX, .9*\EX) --
611       (.9*\EX, .9*\EX) --
612       (.5*\EX, .1*\EX) --
613     cycle;
614   }
615 }
616 \DeclareMathOperator { \tlsymbmaxprevalence } {
617   \_temporal_logic_render_op:n {
618     \draw
619       (.1*\EX, .1*\EX) --
620       (.9*\EX, .1*\EX) --
621       (.5*\EX, .9*\EX) --
622     cycle;
623   }
624 }
625 \DeclareMathOperator { \tlsymbpastmaxprevalence } {
626   \_temporal_logic_render_op:n {
627     \draw[fill]
628       (.1*\EX, .1*\EX) --
629       (.9*\EX, .1*\EX) --
630       (.5*\EX, .9*\EX) --
631     cycle;
632   }
633 }
634 \ProvideDocumentCommand { \tlminprevalence } { m O{} } {
635   \_temporal_logic_op_sup_sub:cnn { \tlsymbminprevalence } { #1 } { #2 }
636 }
637 \ProvideDocumentCommand { \tlpastminprevalence } { m O{} } {
638   \_temporal_logic_op_sup_sub:cnn { \tlsymbpastminprevalence } { #1 } { #2 }
639 }
640 \ProvideDocumentCommand { \tlmaxprevalence } { m O{} } {
641   \_temporal_logic_op_sup_sub:cnn { \tlsymbmaxprevalence } { #1 } { #2 }
642 }
643 \ProvideDocumentCommand { \tlpastmaxprevalence } { m O{} } {
644   \_temporal_logic_op_sup_sub:cnn { \tlsymbpastmaxprevalence } { #1 } { #2 }
645 }
646 \ProvideDocumentCommand { \tlopmminprevalence } { m }

```

```

647 { \tlminprevalence{#1}\! }
648 \ProvideDocumentCommand { \tloppastminprevalence } { m }
649 { \tlpastminprevalence{#1}\! }
650 \ProvideDocumentCommand { \tloppastmaxprevalence } { m }
651 { \tlmaxprevalence{#1}\! }
652 \ProvideDocumentCommand { \tloppastmaxprevalence } { m }
653 { \tlpastmaxprevalence{#1}\! }
654
655
656
657 % Bind
658 \DeclareMathOperator { \tlsymbbind } {
659   \__temporal_logic_render_op:n {
660     \draw (.5*\EX, \EX) -- (.5*\EX, 0);
661     \draw
662       (.2*\EX, .3*\EX) ..
663       controls (.4*\EX, .2*\EX) ..
664       (.5*\EX, 0) ..
665       controls (.6*\EX, .2*\EX) ..
666       (.8*\EX, .3*\EX);
667   }
668 }
669 \ProvideDocumentCommand { \tlbind } { m m } {
670   \__temporal_logic_op_sup_sub:cnn { \tlsymbbind } { #1 } { #2 }
671 }
672 \ProvideDocumentCommand { \tloppbind } { m m } { \tlbind{ #1 } { #2 } }
673
674
675
676 % Rise
677 \DeclareMathOperator { \tlsymbrise } {
678   \__temporal_logic_render_op:n {
679     \draw
680       (.1*\EX, .1*\EX) --
681       (.9*\EX, .9*\EX);
682     \draw
683       (.4*\EX, .9*\EX) --
684       (.9*\EX, .9*\EX) --
685       (.9*\EX, .4*\EX);
686   }
687 }
688 \ProvideDocumentCommand { \tlrise } { 0{} } {
689   \__temporal_logic_op_sub:cn { \tlsymbrise } { #1 }
690 }
691 \ProvideDocumentCommand { \tlopprise } { } { \tlrise\! }
692
693
694
695 % Fall
696 \DeclareMathOperator { \tlsymbfall } {
697   \__temporal_logic_render_op:n {
698     \draw
699       (.1*\EX, .9*\EX) --
700       (.9*\EX, .1*\EX);

```

```

701         \draw
702         (.4*\EX, .1*\EX) --
703         (.9*\EX, .1*\EX) --
704         (.9*\EX, .6*\EX);
705     }
706 }
707 \ProvideDocumentCommand { \tlfall } { 0{} } {
708     \__temporal_logic_op_sub:cn { tlsymbfall } { #1 }
709 }
710 \ProvideDocumentCommand { \tlopfall } { } { \tlfall\! }
711
712
713 % Prophecy
714 \DeclareMathOperator { \tlsymbprophecy } {
715     \__temporal_logic_render_op:n {
716         \draw
717         (.1*\EX, .1*\EX) --
718         (.1*\EX, .9*\EX) --
719         (.9*\EX, .5*\EX) --
720         cycle;
721     }
722 }
723 \ProvideDocumentCommand { \tlprophecy } { 0{} } {
724     \__temporal_logic_op_sub:cn { tlsymbprophecy } { #1 }
725 }
726 \ProvideDocumentCommand { \tlopprophecy } { } { \tlprophecy\! }
727
728
729
730 % History
731 \DeclareMathOperator { \tlsymbhistory } {
732     \__temporal_logic_render_op:n {
733         \draw
734         (.9*\EX, .1*\EX) --
735         (.9*\EX, .9*\EX) --
736         (.1*\EX, .5*\EX) --
737         cycle;
738     }
739 }
740 \ProvideDocumentCommand { \tlhistory } { 0{} } {
741     \__temporal_logic_op_sub:cn { tlsymbhistory } { #1 }
742 }
743 \ProvideDocumentCommand { \tlophistory } { } { \tlhistory\! }
744 \ExplSyntaxOff
745 % </package>

```