Quantitative Timed Pattern Matching Developers Manual

0.1.0

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Chapter 1

Overview

This is the documentation for developers of QTPM. The readers are supposed to be familiar with the concepts and the algorithm in [3].

Chapter 2

Todo List

Class DBM

configure include directory for eigen

Chapter 3

Class Index

3.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Chapter 4

Class Documentation

4.1 ans_trait< T > Struct Template Reference

The documentation for this struct was generated from the following file:

- test/bellman_ford_test.cc

4.2 ans_trait< MaxMinSemiring< double > > Struct Reference

Static Public Attributes

- constexpr static const double **ans** = 3.0

The documentation for this struct was generated from the following file:

- test/warshall_froid_test.cc

4.3 ans_trait< MaxMinSemiring< int > > Struct Reference

Static Public Attributes

- static const int **ans** = 3

The documentation for this struct was generated from the following files:

- test/bellman_ford_test.cc
- test/robustness_test.cc

4.4 ans_trait< MinPlusSemiring< double > > Struct Reference

Static Public Attributes

- static const int **ans** = 2
- constexpr static const double **ans** = 2.0

The documentation for this struct was generated from the following files:

- test/bellman_ford_test.cc
- test/warshall_froid_test.cc

4.5 ans_trait< MinPlusSemiring< int > > Struct Reference

Static Public Attributes

- static const int **ans** = 40

The documentation for this struct was generated from the following file:

- test/robustness_test.cc

4.6 BooleanSemiring Class Reference

Public Member Functions

- **BooleanSemiring** (double value)
- **BooleanSemiring** (bool data=false)
- BooleanSemiring **operator+** (const BooleanSemiring &x) const
- void **operator+=** (const BooleanSemiring &x)
- BooleanSemiring **operator*** (const BooleanSemiring &x) const
- void **operator*=** (const BooleanSemiring &x)
- bool **operator!=** (const BooleanSemiring &x) const
- bool **operator==** (const BooleanSemiring &x) const
- BooleanSemiring **star** () const

Static Public Member Functions

- static BooleanSemiring **zero** ()
- static BooleanSemiring **one** ()

Public Attributes

- bool **data**

The documentation for this class was generated from the following file:

- src/weighted_graph.hh

4.7 BoostTAState< SignalVariables > Struct Template Reference

Public Attributes

- bool **isInit**
- bool **isMatch**
- std::vector< Constraint< SignalVariables > > **label**

The documentation for this struct was generated from the following file:

- src/timed_automaton.hh

4.8 BoostTATransition< ClockVariables > Struct Template Reference

Public Attributes

- ResetVars< ClockVariables > resetVars
- std::vector< Constraint< ClockVariables > > **guard**

4.8.1 Member Data Documentation

4.8.1.1 resetVars

```
template<class ClockVariables >
ResetVars<ClockVariables> BoostTATransition< ClockVariables >::resetVars
```

Note

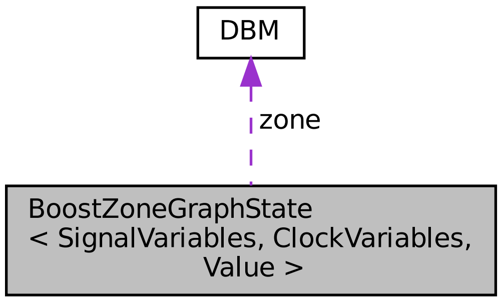
this structure is necessary because of some problem in boost graph

The documentation for this struct was generated from the following file:

- src/timed_automaton.hh

4.9 BoostZoneGraphState< SignalVariables, ClockVariables, Value > Struct Template Reference

Collaboration diagram for BoostZoneGraphState< SignalVariables, ClockVariables, Value >:



Public Attributes

- BoostTimedAutomaton< SignalVariables, ClockVariables >::vertex_descriptor vertex

  The corresponding state in the TA.
- bool jumpable

  The flag showing if one can fire a (discrete) transition. This is used to forbid having multiple jumps at the same time.
- DBM zone

  The corresponding zone.
- std::vector< std::vector< Value > > valuations

  The signal valuations observed after the latest (discrete) transition.

4.9.1 Member Data Documentation

4.9.1.1 jumpable

```
template<class SignalVariables , class ClockVariables , class Value >
bool BoostZoneGraphState< SignalVariables, ClockVariables, Value >::jumpable
```

The flag showing if one can fire a (discrete) transition. This is used to forbid having multiple jumps at the same time.

Note

In the current implementation, this flag is unnecessary because we have the following:

```
jumpable == !(valuations.empty())
```

The documentation for this struct was generated from the following file:

- src/zone_graph.hh

4.10 Constraint< ClockVariables > Struct Template Reference

A constraint in a guard of transitions.

```
#include <constraint.hh>
```

Public Types

- enum class **Order** { **lt** , **le** , **ge** , **gt** }
- using **Interpretation** = std::vector< double >

Public Member Functions

- bool **satisfy** (double d) const
- ::Order **operator()** (Interpretation val) const

Public Attributes

- ClockVariables **x**
- Order **odr**
- int **c**

4.10.1 Detailed Description

template<class ClockVariables>
struct Constraint< ClockVariables >

A constraint in a guard of transitions.

The documentation for this struct was generated from the following file:

- src/constraint.hh

4.11 ConstraintMaker< ClockVariables > Class Template Reference

Public Member Functions

- **ConstraintMaker** (ClockVariables x)
- Constraint< ClockVariables > **operator<** (int c)
- Constraint< ClockVariables > **operator<=** (int c)
- Constraint< ClockVariables > **operator>** (int c)
- Constraint< ClockVariables > **operator>=** (int c)

The documentation for this class was generated from the following file:

- src/constraint.hh

4.12 DBM Struct Reference

Implementation of a zone with DBM DBM For the detail of DBMs, see for example [1].

```
#include <dbm.hh>
```

Public Types

- using **Tuple** = std::tuple< std::vector< Bounds >, Bounds >

Public Member Functions

- std::size_t getNumOfVar () const

  Returns the number of the variables represented by this zone.
- void **cutVars** (std::shared_ptr< DBM > &out, std::size_t from, std::size_t to) const
- std::tuple< std::vector< Bounds >, Bounds > toTuple () const

  Return the tuple representation of the DBM.
- void tightenWithoutClose (uint8_t x, uint8_t y, Bounds c)

  add the constraint x - y <= (c,s) but does not close.
- void tighten (uint8_t x, uint8_t y, Bounds c)

  add the constraint $x - y \leq (c, s)$
- void **close1** (uint8_t x)
- void **reset** (uint8_t x)
- void release (uint8_t x)
- void elapse ()

  Assign the strongest post-condition of the delay.
- void canonize ()

  make the zone canonical
- bool isSatisfiableWithoutCanonize () const

  check if the zone is satisfiable
- bool isSatisfiable ()

  check if the zone is satisfiable
- void abstractize ()

  truncate the constraints compared with a constant greater than or equal to M
- void makeUnsat ()

  make the zone unsatisfiable
- bool **operator==** (DBM z) const
- void **operator&=** (const DBM &z)
- bool **operator>** (const DBM &z) const
- bool **operator<=** (const DBM &z) const
- void convexUnion (const DBM &z, DBM &dest) const

  Make the convex union of two DBMs.
- bool merge (const DBM &z)

  Try to merge the given DBM to this DBM.
- bool **isCanonized** () const

Static Public Member Functions

- static DBM zero (int size)

  Make the zone of size `size` such that all the values are zero.

Public Attributes

- Eigen::Matrix< Bounds, Eigen::Dynamic, Eigen::Dynamic > value

  The matrix representing the DBM.
- Bounds M

  The threshold for the normalization.

4.12.1 Detailed Description

Implementation of a zone with DBM DBM For the detail of DBMs, see for example [1].

Todo configure include directory for eigen

Note

Internally, the variable 0 is used for the constant while externally, the actual clock variable is 0 origin, i.e., the variable 0 for the user is the variable 1 internally. So, we need increment or decrement to fill the gap.

4.12.2 Member Function Documentation

4.12.2.1 convexUnion()

```
void DBM::convexUnion (
            const DBM & z,
            DBM & dest ) const  [inline]
```

Make the convex union of two DBMs.

The convex union is the smallest DBM containing the given DBMs.

Parameters

in	*z*	The DBM to take the convex union
out	*dest*	The DBM to write the resulting convex union

Precondition

getNumOfVar() == z.getNumOfVar() == dest.getNumOfVar()

4.12.2.2 elapse()

```
void DBM::elapse ( )  [inline]
```

Assign the strongest post-condition of the delay.

Note

We do not allow time elapse of duration zero

4.12.2.3 getNumOfVar()

```
std::size_t DBM::getNumOfVar ( ) const  [inline]
```

Returns the number of the variables represented by this zone.

Returns

The number of the variables

4.12.2.4 isSatisfiableWithoutCanonize()

```
bool DBM::isSatisfiableWithoutCanonize ( ) const  [inline]
```

check if the zone is satisfiable

Precondition

The zone is canonical

4.12.2.5 merge()

```
bool DBM::merge (
             const DBM & z )  [inline]
```

Try to merge the given DBM to this DBM.

∗this is updated to the convex union of ∗this and z if it is the union of them. This happens if and only if one of them includes the other or two zones are adjacent.

Parameters

in	*z*	The DBM to merge

Return values

true	when the convex union is the union
false	when the convex union is not the union

4.12.2.6 release()

```
void DBM::release (
             uint8_t x )  [inline]
```

Note

the result is not canonized

4.12.2.7 tightenWithoutClose()

```
void DBM::tightenWithoutClose (
             uint8_t x,
             uint8_t y,
             Bounds c )  [inline]
```

add the constraint x - y <= (c,s) but does not close.

Note

The result is not canonized

The documentation for this struct was generated from the following file:

- src/dbm.hh

4.13 MaxMinSemiring< Base > Class Template Reference

Public Member Functions

- **MaxMinSemiring** (Base data=std::numeric_limits< Base >::infinity())
- MaxMinSemiring **operator+** (const MaxMinSemiring &x) const
- void **operator+=** (const MaxMinSemiring &x)
- MaxMinSemiring **operator*** (const MaxMinSemiring &x) const
- void **operator*=** (const MaxMinSemiring &x)
- bool **operator!=** (const MaxMinSemiring &x) const
- bool **operator==** (const MaxMinSemiring &x) const
- MaxMinSemiring **star** () const

Static Public Member Functions

- static MaxMinSemiring **one** ()
- static MaxMinSemiring **zero** ()

Public Attributes

- Base **data**

The documentation for this class was generated from the following file:

- src/weighted_graph.hh

4.14 MaxPlusSemiring< Base > Class Template Reference

Public Member Functions

- **MaxPlusSemiring** (Base data=0)
- MaxPlusSemiring **operator+** (const MaxPlusSemiring &x) const
- void **operator+=** (const MaxPlusSemiring &x)
- MaxPlusSemiring **operator∗** (const MaxPlusSemiring &x) const
- void **operator∗=** (const MaxPlusSemiring &x)
- bool **operator!=** (const MaxPlusSemiring &x) const
- bool **operator==** (const MaxPlusSemiring &x) const
- MaxPlusSemiring **star** () const

Static Public Member Functions

- static MaxPlusSemiring **zero** ()
- static MaxPlusSemiring **one** ()

Public Attributes

- Base **data**

The documentation for this class was generated from the following file:

- src/weighted_graph.hh

4.15 MinPlusSemiring< Base > Class Template Reference

Public Member Functions

- **MinPlusSemiring** (Base data=0)
- MinPlusSemiring **operator+** (const MinPlusSemiring &x) const
- void **operator+=** (const MinPlusSemiring &x)
- MinPlusSemiring **operator∗** (const MinPlusSemiring &x) const
- void **operator∗=** (const MinPlusSemiring &x)
- bool **operator!=** (const MinPlusSemiring &x) const
- bool **operator==** (const MinPlusSemiring &x) const
- MinPlusSemiring **star** () const

Static Public Member Functions

- static MinPlusSemiring **zero** ()
- static MinPlusSemiring **one** ()

Public Attributes

- Base **data**

The documentation for this class was generated from the following file:

- src/weighted_graph.hh

4.16 num_type_trait< U > Struct Template Reference

Public Types

- using **num_type** = U

The documentation for this struct was generated from the following file:

- src/timed_automaton.hh

4.17 num_type_trait< signed char > Struct Reference

Public Types

- using **num_type** = signed int

The documentation for this struct was generated from the following file:

- src/timed_automaton.hh

4.18 num_type_trait< unsigned char > Struct Reference

Public Types

- using **num_type** = unsigned int

The documentation for this struct was generated from the following file:

- src/timed_automaton.hh

4.19 QuantitativeTimedPatternMatching< SignalVariables, ClockVariables, Weight, Value > Class Template Reference

A class to execute quantitative timed pattern matching.

```
#include <quantitative_timed_pattern_matching.hh>
```

Public Types

- using **ResultMatrix** = std::array< Bounds, 6 >

Public Member Functions

- **QuantitativeTimedPatternMatching** (const TimedAutomaton &TA, const std::vector< TAState > &init←States, const std::function< Weight(const std::vector< Constraint< ClockVariables >> &, const std::vector< std::vector< Value >> &)> &cost, const bool ignoreZero=false)
- void feed (const std::vector< Value > &valuation, const double duration)

  feed one valuation with dwell time
- void **getResult** (boost::unordered_map< ResultMatrix, Weight > &v) const
- boost::unordered_map< ResultMatrix, Weight > & **getResultRef** ()

4.19.1 Detailed Description

template<class SignalVariables, class ClockVariables, class Weight, class Value>
class QuantitativeTimedPatternMatching< SignalVariables, ClockVariables, Weight, Value >

A class to execute quantitative timed pattern matching.

Note

This class works in an incremental way.

4.19.2 Outline of the Automata-Based Algorithm for Quantitative Timed Pattern Matching

The following shows the outline of the algorithm for quantitative timed pattern matching:

1. A piece (u_i, τ_i) of the monitored piecewise constant signal is given to feed.
2. The configurations corresponding to the matching begging from the current piece are added to the "pool" of the current configurations.
3. The zone graph of duration τ_i with values u_i is constructed.
4. For each node of the zone graph, we compute the shortest distance to it by the generalized Bellman-Ford algorithm [2].
5. By forcing the dwell time, we construct the configuration just after the current piece.
6. For the configurations reaching accepting states, we put the resulting matching to this->result.

We use the zone graph for generalized reachability analysis since the transition and the switching of the signal values are asynchronous.

4.19.3 On the Usage of DBM in Quantitative Timed Pattern Matching

The usage of each element in the DBM is as follows.

- 0: x0 == 0
  - i.e., the special element showing the constant 0.
- 1-N: x (usual variables)
- N+1: the duration from the actual start
  - i.e., $\mathrm{NOW} - t$, where t is the beginning of the matching
- N+2: the dwell time
  - i.e., $\mathrm{NOW} - \tau_i$
  - should be released at first
  - THIS SHOULD NOT RESET in zone construction

4.19.4 Member Function Documentation

4.19.4.1 feed()

```
template<class SignalVariables , class ClockVariables , class Weight , class Value >
void QuantitativeTimedPatternMatching< SignalVariables, ClockVariables, Weight, Value >::feed
(
             const std::vector< Value > & valuation,
             const double duration )  [inline]
```

feed one valuation with dwell time

In this function, a piece of the entire piecewise constant function is fed and the matching ending in this piece is added to this->result. See Outline of the Automata-Based Algorithm for Quantitative Timed Pattern Matching for the outline of the algorithm.

Parameters

in	*valuation*	The new signal valuation
in	*duration*	The duration of the given signal valuation

Note

It is not a problem to give the same valuation consecutively.

The documentation for this class was generated from the following file:

- src/quantitative_timed_pattern_matching.hh

4.20 ResetVars< ClockVariables > Struct Template Reference

Public Attributes

- std::vector< ClockVariables > **resetVars**

The documentation for this struct was generated from the following file:

- src/timed_automaton.hh

4.21 weight_label_writer< Graph > Struct Template Reference

Public Member Functions

- **weight_label_writer** (const Graph &g)
- template<class Edge >
  void **operator()** (std::ostream &out, const Edge &edge) const

The documentation for this struct was generated from the following file:

- src/zone_graph.hh

4.22 ZoneGraphLabelWriter< ZoneGraph, TimedAutomaton, Weight > Struct Template Reference

Public Member Functions

- **ZoneGraphLabelWriter** (const ZoneGraph &ZG, const TimedAutomaton &TA, const std::unordered_map< typename ZoneGraph::vertex_descriptor, Weight > &distance)
- template<class Vertex >
  void **operator()** (std::ostream &out, const Vertex &vertex) const

The documentation for this struct was generated from the following file:

- src/zone_graph.hh

Bibliography

[1] Johan Bengtsson and Wang Yi. Timed automata: Semantics, algorithms and tools. In Jörg Desel, Wolfgang Reisig, and Grzegorz Rozenberg, editors, *Lectures on Concurrency and Petri Nets, Advances in Petri Nets [This tutorial volume originates from the 4th Advanced Course on Petri Nets, ACPN 2003, held in Eichstätt, Germany in September 2003. In addition to lectures given at ACPN 2003, additional chapters have been commissioned]*, volume 3098 of *Lecture Notes in Computer Science*, pages 87–124. Springer, 2003. 5, 12, 13

[2] Mehryar Mohri. *Weighted Automata Algorithms*, pages 213–254. Springer Berlin Heidelberg, Berlin, Heidelberg, 2009. 18

[3] Masaki Waga. Online quantitative timed pattern matching with semiring-valued weighted automata. In Étienne André and Mariëlle Stoelinga, editors, *Formal Modeling and Analysis of Timed Systems - 17th International Conference, FORMATS 2019, Amsterdam, The Netherlands, August 27-29, 2019, Proceedings*, volume 11750 of *Lecture Notes in Computer Science*, pages 3–22. Springer, 2019. 1

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