

MASARYK UNIVERSITY  
FACULTY OF INFORMATICS



# **Parameter Synthesis from Hypotheses Formulable in CTL Logic**

BACHELOR THESIS

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## **Declaration**

Hereby I declare, that this paper is my original authorial work, which I have worked out by my own. All sources, references and literature used or excerpted during elaboration of this work are properly cited and listed in complete reference to the due source.

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**Advisor:** John Foo, Ph.D.

## **Acknowledgement**

I would like to thank my supervisor ...

## **Abstract**

The aim of the bachelor work is to provide ...

## Keywords

keyword1, keyword2 ...

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# 1 Introduction

Lorem Ipsum [?]

## 2 Algorithm

In this chapter, we describe the distributed algorithm that computes the assumption function  $\mathcal{A}$ .

### 2.1 Distributed Environment

In this section, we briefly describe the distributed environment assumed by our algorithm, in order to prevent any possible confusion.

We assume a distributed environment with fixed number of reliable processes connected by reliable, order-preserving channels (The order preservation can be relaxed to some extent). We also assume that each process has a fixed identifier and the set of all process identifiers equals the result set of the partition function.

Several parts of the algorithm do not have explicit termination (they terminate by reaching deadlock - no messages are exchanged between processes). In such cases, suitable termination detection algorithm is employed to detect this deadlock and terminate computation properly. Our implementation uses Safra's algorithm [CITATION] for this purpose, but the related code has been skipped for easier readability.

### 2.2 Algorithm outline

The main idea of the algorithm is described in REFERENCE and resembles other CTL model checking algorithms.

```
1: procedure CHECKCTL( $\phi, \mathcal{K} = (id, f, \mathcal{P}, S, I, \xrightarrow{p}, L)$ )
2:    $\mathcal{A} \leftarrow \{(p, s, \alpha, \text{tt}) \mid p \in \mathcal{P} \wedge \alpha \in L(s)\}$ 
3:   for all  $i < |\phi|$  do
4:     for all  $\psi$  in  $cl(\phi)$  where  $|\psi| = i$  do
5:        $\mathcal{A} \leftarrow \text{CHECKFORMULA}(\psi, \mathcal{K}, \mathcal{A})$ 
6:     end for
7:   end for
8: end procedure
```

The algorithm starts by initializing the assumption function using the labeling function defined in *kripke* fragment. After that, it tra-



verses the structure of formula, starting from smallest formulas and uses computed results to process more complex formulas. Function `CHECKFORMULA` computes all states and colors where formula  $\psi$  holds and returns assumption function updated accordingly. This is done using the local information contained in given kripke fragment, assumptions previously computed for smaller formulas and also by communicating with other processes. Note that only assumptions relevant for particular process are computed and returned (each process has information only about it's own state space).

### 2.3 Common operations

In this section, we define functions used to simplify the algorithm description. Let us fix a formula  $\phi$  and a parametrised kripke fragment  $\mathcal{K} = (id, f, \mathcal{P}, S, I, \xrightarrow{p}, L)$  as input of the algorithm.

Intuitively, function  $validStates : cl(\phi) \times AS_{\mathcal{K}}^{\phi} \rightarrow S \times 2^{\mathcal{P}}$  computes a set of states and parameters where truth of given formula is assumed. It is also responsible for handling of boolean operators, since these can be computed without any inter-process communication.

$$validStates(\phi_1 \wedge \phi_2, \mathcal{A}) = \{(s, p) \mid \mathcal{A}(s, p, \phi_2) = \text{tt} \wedge \mathcal{A}(s, p, \phi_1) = \text{tt}\}$$

$$validStates(\phi_1 \vee \phi_2, \mathcal{A}) = \{(s, p) \mid \mathcal{A}(s, p, \phi_2) = \text{tt} \vee \mathcal{A}(s, p, \phi_1) = \text{tt}\}$$

$$validStates(\neg\phi, \mathcal{A}) = \{(s, p) \mid \mathcal{A}(s, p, \phi) = \text{ff}\}$$

$$validStates(\phi, \mathcal{A}) = \{(s, p) \mid \mathcal{A}(s, p, \phi) = \text{tt}\}$$

Function  $predecessors : S \rightarrow S \times 2^{\mathcal{P}}$  computes set of direct predecessors of given node including the color sets labeling the appropriate transitions.

$$predecessors(to) = \{(from, P) \mid P = \{p \mid from \xrightarrow{p} to\}\}$$

Symmetrically, function  $successors : S \rightarrow S \times 2^{\mathcal{P}}$  computes set of direct successors of given node including the color sets labeling the appropriate transitions.

$$\text{predecessors}(\text{from}) = \{(to, P) \mid P = \{p \mid \text{from} \xrightarrow{p} to\}\}$$

## 2.4 Exist Next Operator

```

1: Process variables:
2:  $\mathcal{K} = (id, f, \mathcal{P}, S, I, \xrightarrow{p}, L)$  ▷ Kripke fragment
3:  $\phi = \text{EX}\phi_1$  ▷ CTL formula
4:  $\mathcal{A}$  ▷ Initial assumption function
5: procedure INIT
6:   for all  $state$  in  $\text{validStates}(\phi_1, \mathcal{A}, \mathcal{K})$  do
7:     for all  $(pred, \text{tranCol})$  in  $\text{predecessors}(state, \mathcal{K})$  do
8:        $\text{SEND}(f(state), (pred, \mathcal{P} \cup \text{tranCol}))$ 
9:     end for
10:  end for
11: end procedure
12: procedure RECEIVE( $colSet, to$ )
13:    $\mathcal{A} \leftarrow \mathcal{A} \cup \{(p, to, \phi) \mid p \in colSet\}$ 
14: end procedure

```

## 2.5 Exist Until Operator

```

1: Process variables:
2:  $\mathcal{K} = (id, f, \mathcal{P}, S, I, \xrightarrow{p}, L)$  ▷ Kripke fragment
3:  $\phi = \text{E}\phi_1 \text{U}\phi_2$  ▷ CTL formula
4:  $\mathcal{A}$  ▷ Initial assumption function
5: procedure INIT
6:   for all  $state$  in  $\text{validStates}(\phi_2, \mathcal{A}, \mathcal{K})$  do
7:      $\mathcal{A} \leftarrow \mathcal{A} \cup (\mathcal{P}, state, \phi)$ 
8:     for all  $(pred, \text{tranCol})$  in  $\text{predecessors}(state, \mathcal{K})$  do
9:        $\text{SEND}(f(state), (state, pred, \mathcal{P} \cup \text{tranCol}))$ 
10:    end for
11:  end for
12: end procedure
13: procedure RECEIVE( $colSet, from, to$ )
14:    $colSet \leftarrow colSet \cap \text{valid}(\phi_1, to, \mathcal{A})$ 
15:   if  $colSet \neq \emptyset$  and  $colSet \setminus \text{valid}(\phi, to, \mathcal{A}) \neq \emptyset$  then

```

---

```

16:    $\mathcal{A} \leftarrow \mathcal{A} \cup (\text{colSat}, to, \phi)$ 
17:   for all  $(pred, \text{tranCol})$  in  $\text{predecessors}(to, \mathcal{K})$  do
18:      $\text{SEND}(f(pred), (to, pred, \text{colSat} \cup \text{tranCol}))$ 
19:   end for
20: end if
21: end procedure

```

## 2.6 All Until Operator

```

1: Process variables:
2:  $\mathcal{K} = (id, f, \mathcal{P}, S, I, \xrightarrow{p}, L)$  ▷ Kripke fragment
3:  $\phi = A\phi_1 U \phi_2$  ▷ CTL formula
4:  $S = \emptyset$ 
5:  $\mathcal{A}$  ▷ Initial assumption function
6: procedure INIT
7:   for all  $state$  in  $\text{validStates}(\phi_2, \mathcal{K})$  do
8:     for all  $(pred, \text{tranCol})$  in  $\text{predecessors}(state, \mathcal{K})$  do
9:        $\text{SEND}(f(state), (state, pred, \mathcal{P} \cup \text{tranCol}))$ 
10:    end for
11:  end for
12: end procedure
13: procedure RECEIVE( $\text{colSet}, from, to$ )
14:    $S \leftarrow S \cup (to, from, \text{colSet})$ 
15:    $\text{colSet} \leftarrow \text{colSet} \cap \text{valid}(\phi_1, to, \mathcal{K})$ 
16:   if  $\text{colSet} \neq \emptyset$  and  $\text{colSet} \setminus \text{valid}(\phi, to, \mathcal{K}) \neq \emptyset$  then
17:      $\mathcal{A} \leftarrow \mathcal{A} \cup (\text{colSat}, to, \phi)$ 
18:     for all  $(pred, \text{tranCol})$  in  $\text{predecessors}(to, \mathcal{K})$  do
19:        $\text{SEND}(f(pred), (to, pred, \text{colSat} \cup \text{tranCol}))$ 
20:     end for
21:   end if
22: end procedure

```

## A First appendix

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

This is the second paragraph. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

And after the second paragraph follows the third paragraph. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

After this fourth paragraph, we start a new paragraph sequence. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information

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## B Another appendix

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