TEXAS STATE UNIVERSITY

CTL MODEL CHECKER

A project submitted in fulfilment of the requirements for the course

CS 5392 – FORMAL METHODS IN SOFTWARE ENGINEERING

By

MORGAN LANGLAIS
SRI NAGA VINDU GOLUGURI
ALKA RAGHAV
VINAY LOKESH

Submitted to,
Dr. Rodion Podorozhny
Professor
Texas State University
San Marcos, Texas -78666
rp31@txstate.edu

TEXAS STATE
COMPUTER SCIENCE

Department of Computer Science
Texas State University
601 University Dr, San Marcos, Texas-78666

Summer-2020

INDEX

CHAPTER 1

PROBLEM DESCRIPTION

1.1 Problem Statement

In the field of computers, it is a demanding task to comply with safety requirements. Verification of digital hardware designs is becoming an increasingly complex task as the designs are incorporating more functionality, becoming complex and growing larger in size. This gives rise to model checking which is a method for checking whether a finite state model of a system meets the given specification. A model checking tool accepts system requirements, design or a property that a final system is expected to satisfy. The idea is that by ensuring that the model satisfies enough system properties, we increase our support in the correctness of the model. The system requirements are called models because they represent requirements or design. Most real-time embedded or safety-critical systems are control-oriented rather than data-oriented indicating the dynamic behavior is much more important than business logic. Syntax checking plays a vital role in identifying and safeguarding the business logic and more importantly control logic.

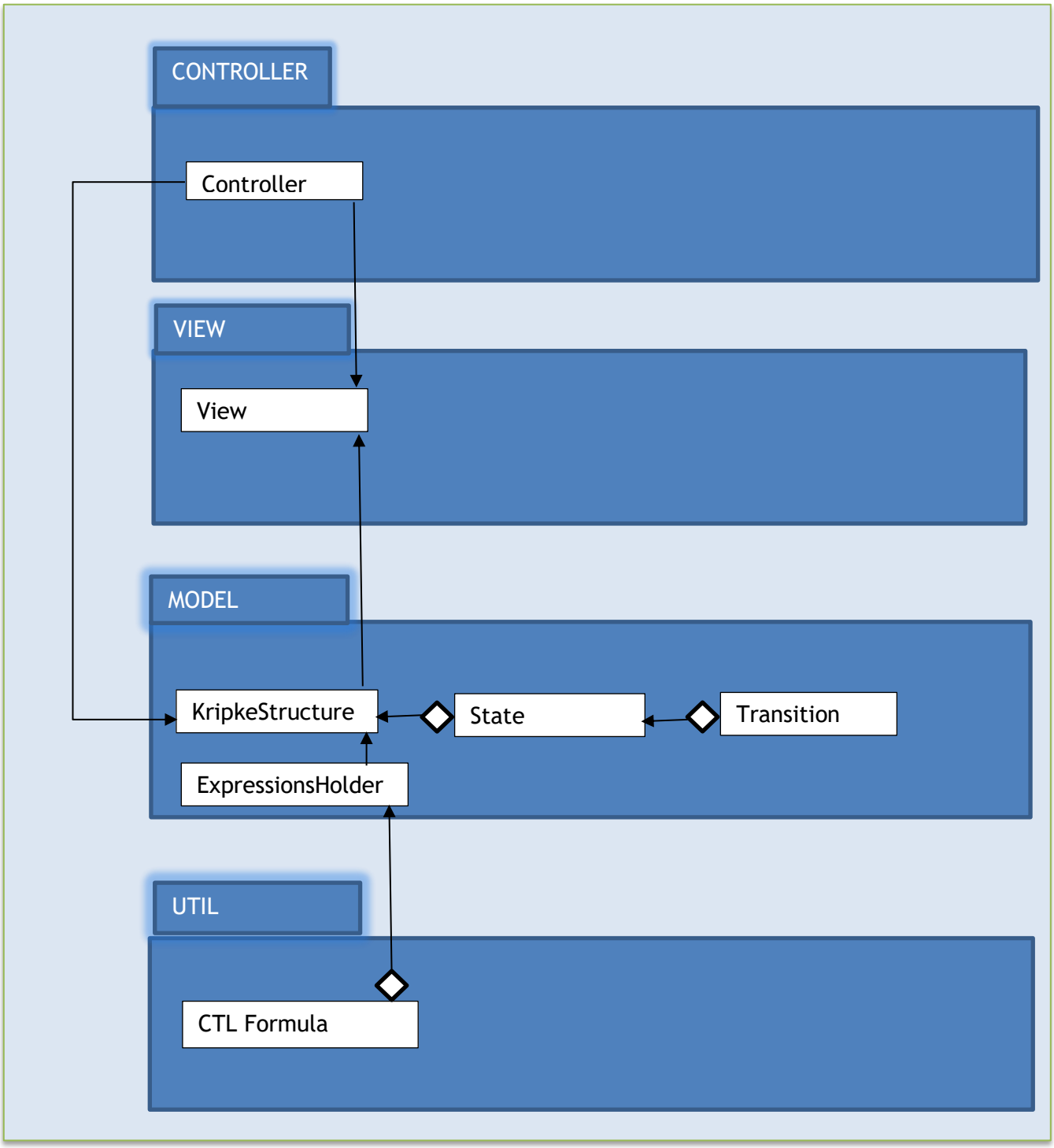
1.2Problem Solution

In this application we have implemented a model checking analysis tool for verification of properties defined in CTL temporal logic. Computational Tree Logic(CTL) is a branching-time logic implying that the model of time is tree structure in which the future is not determined. In the context of our application we analyze and check for the correctness of Kripke Structure's property which is defined by the CTL formula. Kripke is widely used in model checking, it is a variation of transition system which is basically a graph whose nodes represent the reachable states of the system and whose edges represent transitions. We focus on the Boolean Satisfiability(SAT) based formal verification, In formal verification, the conformance of a design to a given set of specifications is proven mathematically, thereby leaving less room for unexplored search spaces. In this Java standalone application which takes the definition of Kriple structure as its input, accepts the state ID for whose property is defined by the CTL formula. The application thoroughly performs syntax checking and provides messages if a Kripke definition can be parsed. The definition language for the CTL follows CTL syntax. For instance, operators and, or, not,-> EX, AX, EF, AF, EG, AG, E[p U q], A[p U q]]

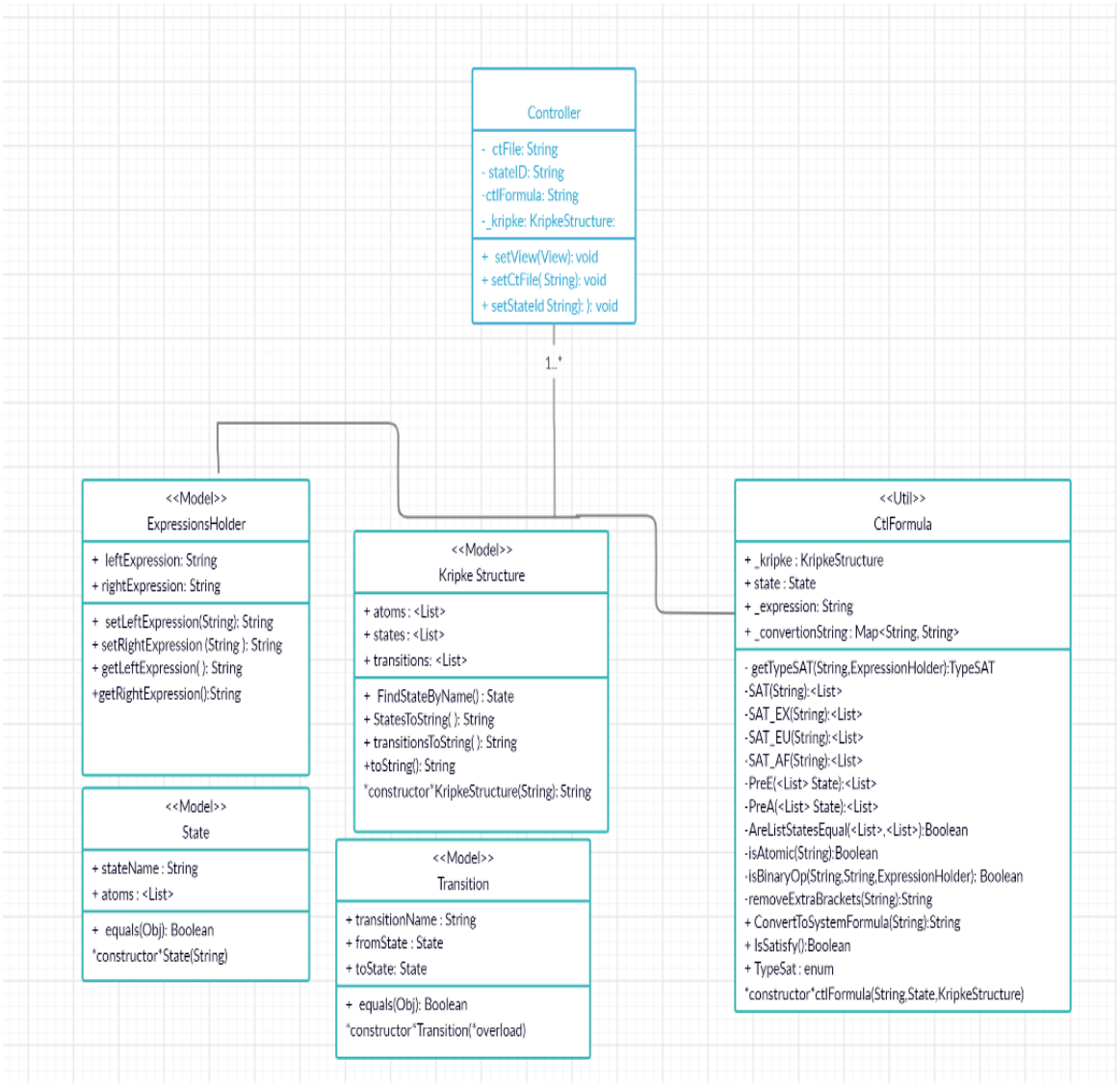
CHAPTER 2

PROBLEM VISUALIZATION

2.1 UML Diagram for CTL Model



2.2 Class Diagram for CTL Model



CHAPTER 3
PROBLEM OUTPUT

Output 1: EGp and AGp in State 1 and Model 1

```
Please enter the location for the CTL formula:
model1
Please enter the state ID:
s1
Please enter the CTL formula:
EGp and AGq
Original Expression: EGp & AGq
Type SAT: And
Left Expression: EGp
Right Expression:  AGq
-----------------------------------
Original Expression: EGp
Type SAT: EG
Left Expression: p
Right Expression:
-----------------------------------
Original Expression: !AF!p
Type SAT: Not
Left Expression: AF!p
Right Expression:
-----------------------------------
Original Expression: AF!p
Type SAT: AF
Left Expression: !p
Right Expression:
-----------------------------------
```

```
Original Expression: !p
Type SAT: Not
Left Expression: p
Right Expression:
-----------------------------------
Original Expression: p
Type SAT: Atomic
Left Expression: p
Right Expression:
-----------------------------------
Original Expression:  AGq
Type SAT: AG
Left Expression:
Right Expression: q
-----------------------------------
Original Expression: !EF!
Type SAT: Not
Left Expression: EF!
Right Expression:
-----------------------------------
Original Expression: EF!
Type SAT: EF
Left Expression: !
Right Expression:
-----------------------------------
Original Expression: E(TU!)
Type SAT: EU
Left Expression: T
Right Expression: !
```

```
Original Expression: T
Type SAT: AllTrue
Left Expression: T
Right Expression:
-----------------------------------
Original Expression: !
Type SAT: Not
Left Expression:
Right Expression:
-----------------------------------
Original Expression:
Type SAT: Atomic
Left Expression:
Right Expression:
-----------------------------------

Property EGp and AGq does not hold in state s1!
```

Output 2: AXq or A(pUq) in State 3 and Model 1

```
Please enter the location for the CTL formula:
model1
Please enter the state ID:
s3
Please enter the CTL formula:
AXq or A(pUq)
Original Expression: AXq | A(pUq)
Type SAT: Or
Left Expression: AXq
Right Expression:  A(pUq
-----------------------------------
Original Expression: AXq
Type SAT: AX
Left Expression: q
Right Expression:
-----------------------------------
Original Expression: !EX!q
Type SAT: Not
Left Expression: EX!q
Right Expression:
-----------------------------------
Original Expression: EX!q
Type SAT: EX
Left Expression: !q
Right Expression:
-----------------------------------
```

```
Original Expression: !q
Type SAT: Not
Left Expression: q
Right Expression:
-----------------------------------
Original Expression: q
Type SAT: Atomic
Left Expression: q
Right Expression:
-----------------------------------
Original Expression:  A(pUq
Type SAT: AU
Left Expression: p
Right Expression: q
-----------------------------------
Original Expression: !(E(!qU(!p&!q))|(EG!q))
Type SAT: Not
Left Expression: (E(!qU(!p&!q))|(EG!q)
Right Expression:
-----------------------------------
Original Expression: (E(!qU(!p&!q))|(EG!q)
Type SAT: Or
Left Expression: E(!qU(!p&!q))
Right Expression: (EG!q)
-----------------------------------
Original Expression: E(!qU(!p&!q))
Type SAT: EU
Left Expression: !q
Right Expression: (!p&!q)
-----------------------------------
```

```
Original Expression: !q
Type SAT: Not
Left Expression: q
Right Expression:
-----------------------------------
Original Expression: q
Type SAT: Atomic
Left Expression: q
Right Expression:
-----------------------------------
Original Expression: (!p&!q)
Type SAT: And
Left Expression: !p
Right Expression: !q)
-----------------------------------
Original Expression: !p
Type SAT: Not
Left Expression: p
Right Expression:
-----------------------------------
Original Expression: p
Type SAT: Atomic
Left Expression: p
Right Expression:
-----------------------------------
Original Expression: !q)
Type SAT: Not
Left Expression: q
Right Expression:
-----------------------------------
```

```
Original Expression: q
Type SAT: Atomic
Left Expression: q
Right Expression:
-----------------------------------
Original Expression: (EG!q)
Type SAT: EG
Left Expression: !q)
Right Expression:
-----------------------------------
Original Expression: !AF!!q)
Type SAT: Not
Left Expression: AF!!q
Right Expression:
-----------------------------------
Original Expression: AF!!q
Type SAT: AF
Left Expression: !!q
Right Expression:
-----------------------------------
Original Expression: !!q
Type SAT: Not
Left Expression: !q
Right Expression:
-----------------------------------
Original Expression: !q
Type SAT: Not
Left Expression: q
Right Expression:
-----------------------------------
```

```
-----------------------------------
Original Expression: q
Type SAT: Atomic
Left Expression: q
Right Expression:
-----------------------------------

Property AXq or A(pUq) does not hold in state s3!
```

Output 3: AXq or A(pUq) in State 3 and Model 1

```
Please enter the location for the CTL formula:
model1
Please enter the state ID:
s4
Please enter the CTL formula:
EX((AFp)or(EFr))
Original Expression: EX((AFp)|(EFr))
Type SAT: EX
Left Expression: ((AFp)|(EFr)
Right Expression:
-----------------------------------
Original Expression: ((AFp)|(EFr)
Type SAT: Or
Left Expression: (AFp)
Right Expression: (EFr)
-----------------------------------
Original Expression: (AFp)
Type SAT: AF
Left Expression: p)
Right Expression:
-----------------------------------
Original Expression: p)
Type SAT: Atomic
Left Expression: p
Right Expression:
-----------------------------------
```

```
Original Expression: (EFr)
Type SAT: EF
Left Expression: r)
Right Expression:
-----------------------------------
Original Expression: E(TUr))
Type SAT: EU
Left Expression: T
Right Expression: r)
-----------------------------------
Original Expression: T
Type SAT: AllTrue
Left Expression: T
Right Expression:
-----------------------------------
Original Expression: r)
Type SAT: Atomic
Left Expression: r
Right Expression:
-----------------------------------

Property EX((AFp)or(EFr)) holds in state s4!
```

Output 4: AG(t1 -> AF c1) in model 4 and state 1

```
Please enter the location for the CTL formula:
model4
Please enter the state ID:
s1
Please enter the CTL formula:
AG(t1 -> AF c1)
Original Expression: AG(t1 > AF c1)
Type SAT: AG
Left Expression:
Right Expression: (t1 > AF c1
-----------------------------------
Original Expression: !EF!
Type SAT: Not
Left Expression: EF!
Right Expression:
-----------------------------------
Original Expression: EF!
Type SAT: EF
Left Expression: !
Right Expression:
-----------------------------------
Original Expression: E(TU!)
Type SAT: EU
Left Expression: T
Right Expression: !
-----------------------------------
```

```
Original Expression: T
Type SAT: AllTrue
Left Expression: T
Right Expression:
-----------------------------------
Original Expression: !
Type SAT: Not
Left Expression:
Right Expression:
-----------------------------------
Original Expression:
Type SAT: AllTrue
Left Expression:
Right Expression:
-----------------------------------

Property AG(t1 -> AF c1) holds in state s1!
```

Output 5: AG(t1 -> AF c1) in model 4 and state 6

```
Please enter the location for the CTL formula:
model4
Please enter the state ID:
s6
Please enter the CTL formula:
AG(t1 -> AF c1)
Original Expression: AG(t1 > AF c1)
Type SAT: AG
Left Expression:
Right Expression: (t1 > AF c1
-----------------------------------
Original Expression: !EF!
Type SAT: Not
Left Expression: EF!
Right Expression:
-----------------------------------
Original Expression: EF!
Type SAT: EF
Left Expression: !
Right Expression:
-----------------------------------
Original Expression: E(TU!)
Type SAT: EU
Left Expression: T
Right Expression: !
-----------------------------------
```

```
Original Expression: T
Type SAT: AllTrue
Left Expression: T
Right Expression:
-----------------------------------
Original Expression: !
Type SAT: Not
Left Expression:
Right Expression:
-----------------------------------
Original Expression:
Type SAT: AllTrue
Left Expression:
Right Expression:
-----------------------------------

Property AG(t1 -> AF c1) holds in state s6!
```

Output 6: EFe and !Axe in modelmicrowave and state 1

Please enter the location for the CTL formula:

modelmicrowave

Please enter the state ID:

s1

Please enter the CTL formula:

EFe and !AXe

Original Expression: EFe & !AXe

Type SAT: And

Left Expression: EFe

Right Expression: !AXe

Original Expression: EFe

Type SAT: EF

Left Expression: e

Right Expression:

Original Expression: E(TUe)

Type SAT: EU

Left Expression: T

Right Expression: e

Original Expression: T

Type SAT: AllTrue

Left Expression: T

Right Expression:

Original Expression: e

Type SAT: Atomic

Left Expression: e

Right Expression:

Original Expression: !AXe

Type SAT: Not

Left Expression: AXe

Right Expression:

Original Expression: AXe

Type SAT: AX

Left Expression: e

Right Expression:

Original Expression: !EX!e

Type SAT: Not

Left Expression: EX!e

Right Expression:

Original Expression: EX!e

Type SAT: EX

Left Expression: !e

Right Expression:

Original Expression: !e

Type SAT: Not

Left Expression: e

Right Expression:

Original Expression: e

Type SAT: Atomic

Left Expression: e

Right Expression:

Property EFe and !AXe holds in state s1!

Output 7: EXh in modelmicrowave and state 2

Please enter the location for the CTL formula:

modelmicrowave

Please enter the state ID:

s2

Please enter the CTL formula:

EXh

Original Expression: EXh

Type SAT: EX

Left Expression: h

Right Expression:

Original Expression: h

Type SAT: Atomic

Left Expression: h

Right Expression:

Property EXh does not hold in state s2!

Output 8: AF(c or h) in modelmicrowave and state 7

Please enter the location for the CTL formula:

modelmicrowave

Please enter the state ID:

s7

Please enter the CTL formula:

AF(c or h)

Original Expression: AF(c | h)

Type SAT: AF

Left Expression: (c | h

Right Expression:

Original Expression: (c | h

Type SAT: Or

Left Expression: c

Right Expression: h

Original Expression: c

Type SAT: Atomic

Left Expression: c

Right Expression:

Original Expression: h

Type SAT: Atomic

Left Expression: h

Right Expression:

Property AF(c or h) holds in state s7!

Output 9: Custom Validation for Input

```
Please enter the location for the CTL formula:
kbsajakscjs
Input Format Not Valid


Process finished with exit code 0
```

Output 10: Custom Validation for Input

```
Please enter the location for the CTL formula:
modelmicrowave
Please enter the state ID:
m,a m,
Input Format Not Valid: Right usage s0 - s9


Process finished with exit code 0
```

APPENDIX

This chapter lists contents which are submitted for CTL Model Checker project which is written in Java using intellij IDE.

- ModelCheckCTL\documentation-sum20
  sum20\TestFiles\CTLModelCheckerTestCases\CTLModelCheckerTestCases.docx
  This file contains description of test cases in detail.
- ModelCheckCTL\documentation-sum20\ClassDiagram.png
  This PNG file has the class diagram.
- ModelCheckCTL\ModelCheckCTL
  This folder contains all project source code.