Combining Static and Dynamic Verification for the Analysis of OCaml Programs

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- ▶ Introduction
- State of the Art
- Preliminary Results
- Work Plan

Motivation

Introduction

Programmers need to test software before release.

- Error-prone
- Time-consuming
- More demanding with increasing complexity of systems

Motivation

Introduction

Solutions:

- Extensive testing
- Type-checking (even before testing)
- Automatic runtime verification
  - ... and still all done separately may not be enough!

- what about proof of programs?
  - ... that might be too costly and time-consuming!

Research Questions

Introduction

- *Is it possible to combine static and dynamic verification for OCaml programs?*
    - Is it possible to create an executable subset of GOSPEL?
    - Should we use Runtime Assertion Checking (RAC) when deductive verification fails?

Research Questions

Introduction

- *Is it possible to combine static and dynamic verification for OCaml programs?*
  - Is it possible to create an executable subset of GOSPEL?
  - Should we use Runtime Assertion Checking (RAC) when deductive verification fails?
    - Perhaps...
      - They are not mutually exclusive, if applied correctly.

Research Questions

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Work to be done... but E-ASCL has proven to be of great importance!
Why shouldn't E-GOSPEL follow the same path?

Research Questions

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Monitor is the technique for the job!

Expected Contributions

Introduction

- Research and Identify an executable set of GOSPEL - E-GOSPEL;
    - Translation of contracts defined by user into assertions that can be run
- Implement Monitors that can help with the verification process;
    - Bridge between static and dynamic schools of verification
- Evaluate effectiveness of the verification process with both E-GOSPEL and Monitors;

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Current Approaches

State of the Art

Divided into three sets:

- Combining static and dynamic verification
- Current tools
- Executable Specifications for RAC

Combining Static and Dynamic Verification

State of the Art

- GOSPEL - the best unification for OCaml
    - Previous works done by Soares, Chirica and Pereira in *"Static and Dynamic Verification of OCaml Programs: The Gospel Ecosystem"*
- Cameleer (deductive verification)
- ORTAC (runtime assertion checking)

Current Tools

State of the Art

For dynamic verification:

- JML - Java Modelling Language
- ACSL - ANSI/ISO C Specification Language
    - E-ACSL - executable subset of ACSL
- SPARK - Ada
- ORTAC - for OCaml

Current Tools

State of the Art

For static verification:

- Frama-C
- Cameleer
- SPARK
- KeY - Java
- VeriFast - Java & C

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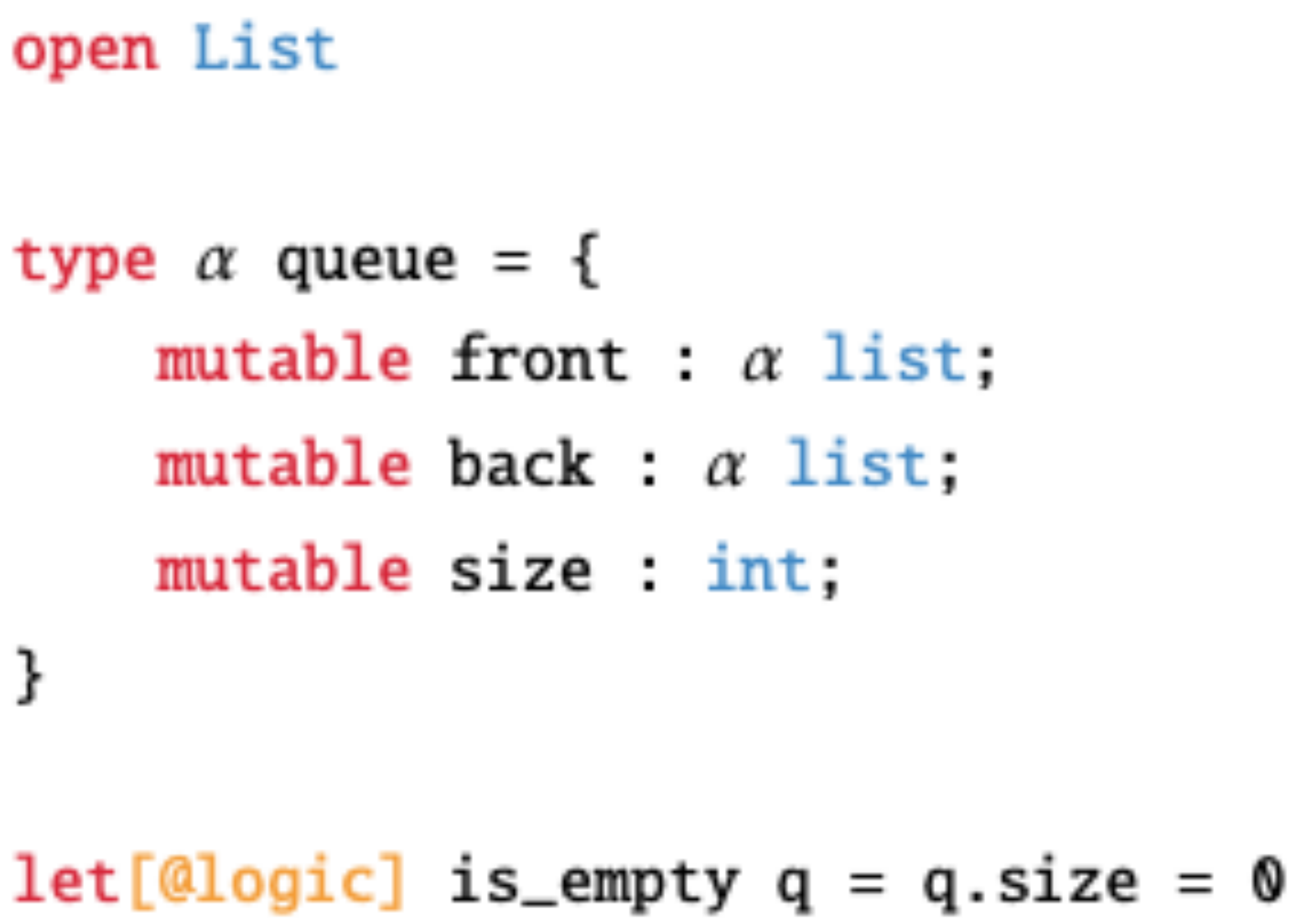
Queue Example

Preliminary Results

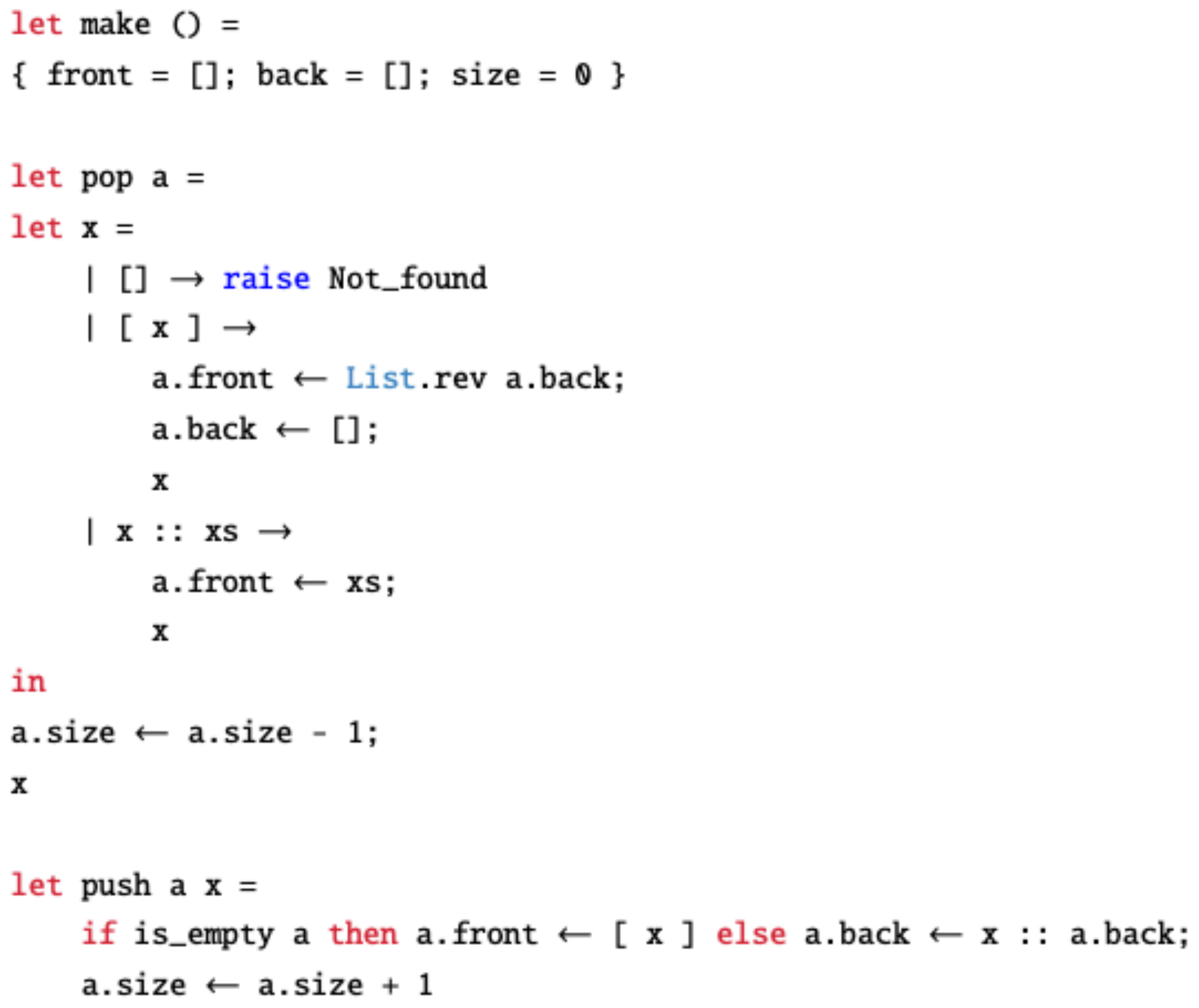
- Simple implementation;
- Straight-forward specifications;
- Use of `List` from OCaml libraries - easy understanding of code;
  - Example becomes much more easier to understand.

Queue Example - Implementation

Preliminary Results



```
open List

type α queue = {
    mutable front : α list;
    mutable back : α list;
    mutable size : int;
}

let[@logic] is_empty q = q.size = 0
```

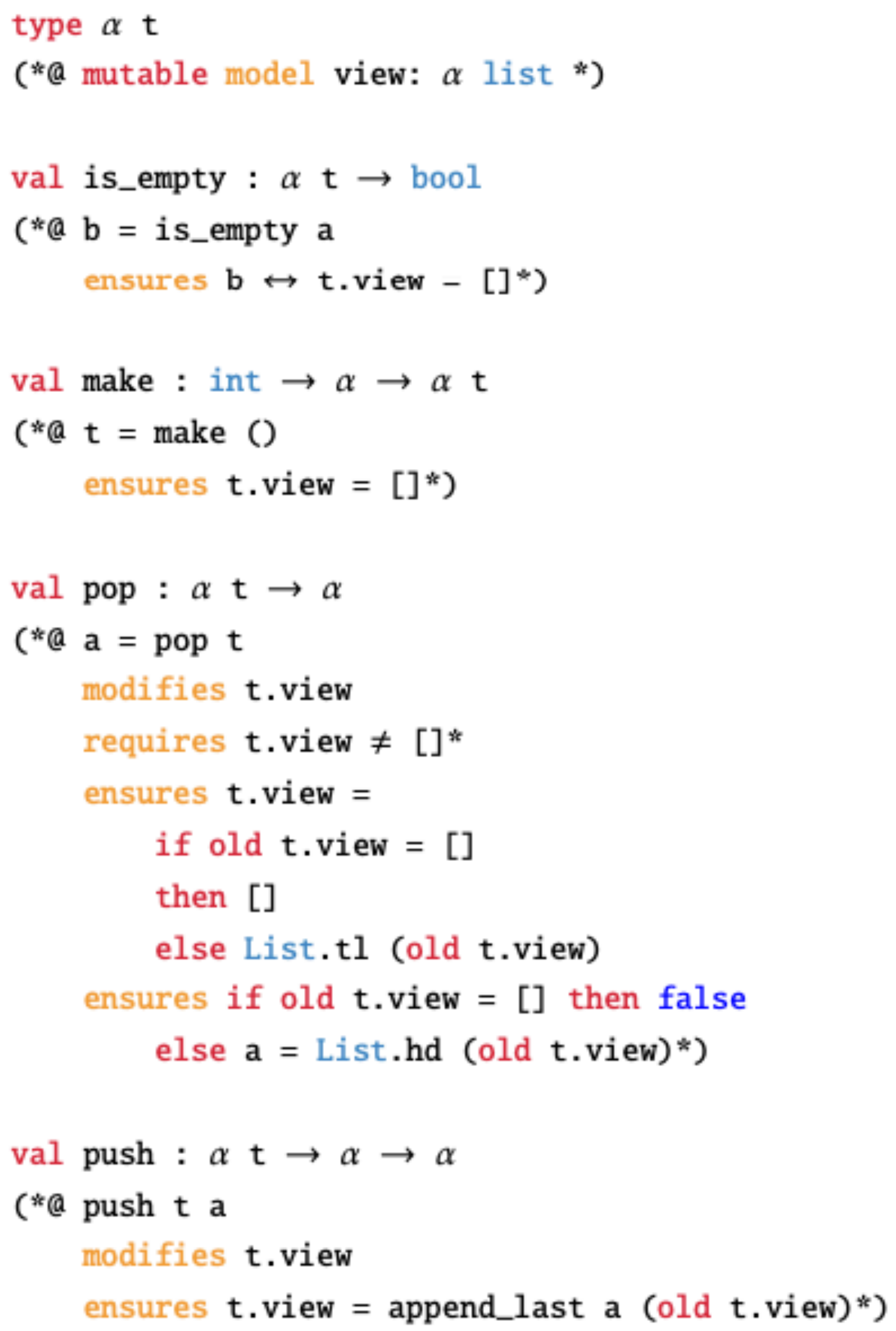


```
let make () =
{ front = []; back = []; size = 0 }

let pop a =
let x =
    | [] → raise Not_found
    | [ x ] →
        a.front ← List.rev a.back;
        a.back ← [];
        x
    | x :: xs →
        a.front ← xs;
        x
in
a.size ← a.size - 1;
x

let push a x =
    if is_empty a then a.front ← [ x ] else a.back ← x :: a.back;
    a.size ← a.size + 1
```

NOTE: The `Queue` is implemented using two elements of type `List`

Queue Example - Specification

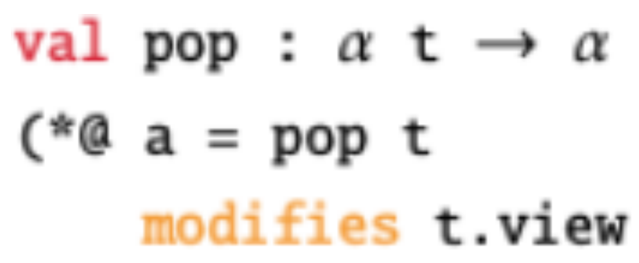
Preliminary Results



```
type α t
(*@ mutable model view: α list *)

val is_empty : α t → bool
(*@ b = is_empty a
    ensures b ↔ t.view = []*)

val make : int → α → α t
(*@ t = make ()
    ensures t.view = []*)

val pop : α t → α
(*@ a = pop t
    modifies t.view
    requires t.view ≠ []*
    ensures t.view =
        if old t.view = []
        then []
        else List.tl (old t.view)
    ensures if old t.view = [] then false
        else a = List.hd (old t.view)*)

val push : α t → α → α
(*@ push t a
    modifies t.view
    ensures t.view = append_last a (old t.view)*)
```

modifies clause for identification of altered elements

Example: `pop` will modify the `t.view` element when the function ends.



```
val pop : α t → α
(*@ a = pop t
    modifies t.view
```

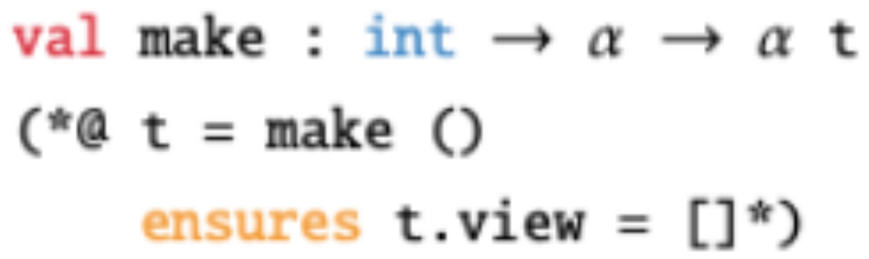
requires handles pre-conditions of functions

Example: `pop` requires that `t.view` must not be empty.

```
val pop : α t → α        requires t.view ≠ []*
```

ensures clause for post-conditions of functions

Example: `make` **always** returns `t.view` as `[]`.



```
val make : int → α → α t
(*@ t = make ()
    ensures t.view = []*)
```

Queue Example - Explanation

Preliminary Results

- Example verified and checked in both Cameleer and ORTAC.
- Error cases:
  1. Errors **in the code**
     - Cameleer - inconclusive proof
     - ORTAC - runtime error
  2. Errors **in the specification**
     - Cameleer - anything can happen
     - ORTAC - anything can happen

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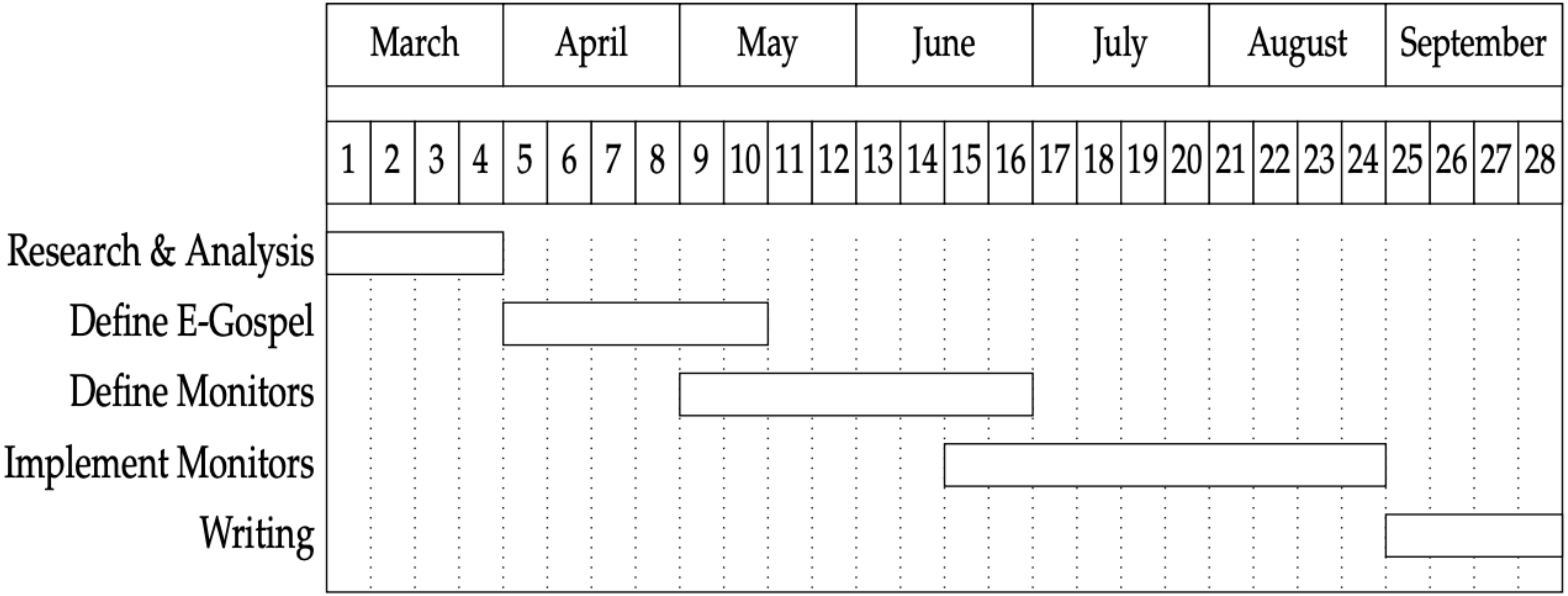
Gantt Chart

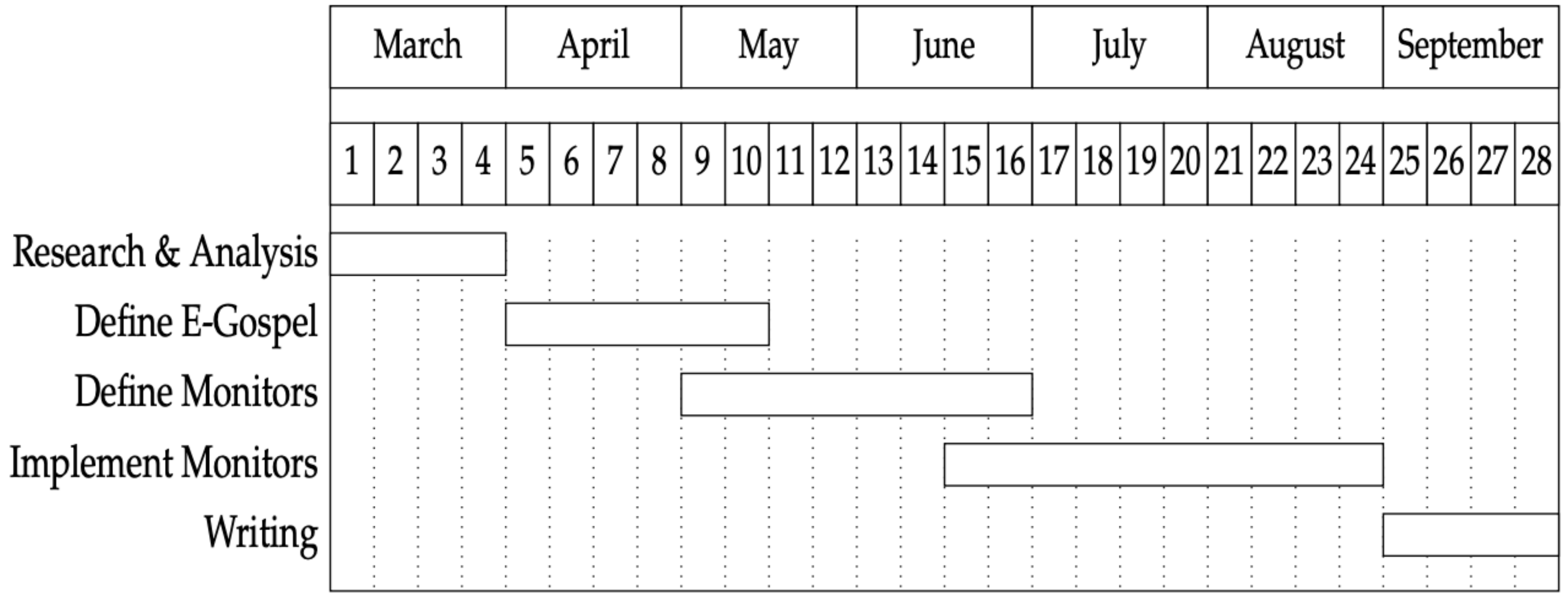
Work Plan



Research & Analysis

Work Plan

- Research study cases
- Analyse cases in ORTAC + Cameleer
- Gather data for future work
- Duration:
  - From first week of March until the end of the month
  - Approximately 4 weeks



Define E-GOSPEL

Work Plan

- Define executable portion of GOSPEL contracts
- Use data and results from *Research & Analyse*
- Duration:
  - From first week of April until the second week of May
  - Approximately 6 weeks

Define Monitors

Work Plan

- Using E-GOSPEL, define the specification of monitors
- Analyse some cases and examples for refinement
- Duration:
  - From first week of May until the end of June
  - Approximately 8 weeks
    - Coincides with *Define E-GOSPEL* as it is concurrent work

Implement Monitors

Work Plan

- Implementation of Monitors using results from previous steps
- Most demanding step - also the most crucial!
- Duration:
  - From second week of June until the end of August
  - Approximately 10 weeks
    - Coincides with *Define Monitors* as it is concurrent work

Writing

Work Plan

- Writing of the dissertation
- Involves all the previous steps' results
- Last work to be done
- Duration:
  - All of September
  - Approximately 4 weeks