MPass: An efficient and computational tool for analysis of message passing programs

User Manual

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1 Introduction

The verification problem such as reachability problem is undecidable for programs having perfect channels even if the number of states in each process are finite but it becomes decidable if we have lossy, stuttering or unordered channels [1]. However, to decide the reachability problem in later case we have high complexity obstacles. Thus in order to avoid this, one useful approach, *context bounding* [6], was proposed recently. This idea limits the number of context switches between two processes because of which we have a trade off between the extent of verification and computational complexity.

MPass is a tool which works on a different approach called as *bounded-phase* reachability analysis. It verifies the reachability problem of programs or protocols having their phase bounded. Each process in such programs can perform a computation in which the number of phases is bounded by some natural number k. In each phase, a process can perform either send transitions or receive transitions (but not both). The transition consisting of no operation, but just the change of states, can be performed in either of these phases. However, this doesn't limit the number of context switches between two process but just the number of alternations between receive and send transitions.

Currently, MPass can decide reachability problem for three types of channel semantics, namely *lossy, stuttering and unordered* channels. These channels allow messages inside them to be lost, dublicated and re-arranged respectively. Details are given in section 3.

This manual provides basic knowledge about the semantics and specification of the model . Detailed information regarding the same can be found in [2].

2 Contact / Bug Report

Feedback, questions, bug reports or any other query related to MPass should be directed to Subham Modi (`smodi@iitk.ac.in`), Gaurav Saini(`sgauarav@iitrpr.ac.in`) verifie

3 MPass Tool

MPass performs two different levels of extraction in order to analyse the reachability problem for a given program.

Verification is achieved by taking the examples from [4] which are further described in [5] and [7]. Bounded Retransmission Protocol is also adapted from [3]. Protocols are used in the format of `xml-files` present within the tool repository inside the 'Includes' folder. The protocols, thus, can be modified in a simple manner by changing the fields in xml-files.

3.1 Xml to Automata

The first task of MPass is to translate the protocols defined in `xml-files` into *Non-Deterministic Finite Automata* (NFA). In order to achieve this, it takes xml-file path of the Protocol as an input and then uses C++ library of `lemon` to translate the protocol into NFA as described below:

```
<rule id="Q0__ack1__INBOUND">
  <pre>
    <current_state>Q0</current_state>
    <received_message>ack1</received_message>
    <channel>c1</channel>
  </pre>
  <post>
    <send_message>mesg0</send_message>
    <next_state>Q1</next_state>
    <channel>c1</channel>
  </post>
</rule>
```

Figure 1: An example of xml code for ABP Protocol

The above rule adds two transitions from the state `Q0` to the state `Q1`. First transition defines the rule of receiving the message `ack1` from the channel `c1` whereas second transition defines the rule of sending the message `mesg0` into the channel `c0`. Each process in a protocol contain one or more such rules which in together defines the automata for that process within the given protocol.

Now, since the protocols have their phase bounded and each phase contain either send or receive transitions (but not both), therefore we make two automata for each process, one containing all except the receive transitions (send copy of that process) and the other containing all except the send transitions (receive copy of that process).
In this way, we have constructed *2*Number of Process* automata for the given protocol.

3.2 Generating Constraint from the above constructed Automata

Verification of protocol for reachability problem is analysed by generating *Presburger Formula* from the automata constructed as shown in `figure 1` and then using the help of modern SMT solver namely *Z3 theorem prover*. Detailed information regarding the framework showing the translation of reachability for *bounded-phase-automata* into the satisfiability of *quantifier-free Presburger formulas* can be found in [2].

In order to generate quantifier-free Presburger formula, certains variables of a particular *sort* have to be defined and thus, for all the transitions present within each automata, we'll introduce a number of variables as shown below in table Table 1::

Variable name	Variable code
Index-variable	i-var
Occurence-variable	o-var
Match-variable	m-var

Table 1: Variables associated with each transitions

Variable declaration and defination are explained briefly in [2].
For taking *bounded-phase-automata* into account, MPass generates variables for both send and receive copy of each process and then duplicates them k times (where k is some natural number denoting the bound for the number of phases within each process) which are then further used to generate Presburger formulas.
If the result of *Z3 theorem prover* for these set of formulas (one of them being displayed in Figure 2) is satisfiable (sat), then the *Bad State* is reachable and we have an UNSAFE (U) condition.

$$(\texttt{occ}\,(t) = 1) \wedge (\texttt{occ}\,(t') = 1) \wedge (\texttt{index}\,(t) < \texttt{index}\,(t')) \Longrightarrow (\texttt{match}\,(t) < \texttt{match}\,(t')).$$

Figure 2: An example of a *quantifier-free Presburger formulas*

4 Installation

MPass Tool can be compiled and installed on Unix-like system.

4.1 Requirements

- A C++ compiler supporting C++11. For example g++ version 4.6 or higher.
- Z3 SMT 2.0 Solver. Also Z3 SMT solver should be installed in the bin directory so that it can be called using "z3 -smt2 filename" from the terminal. It can be downloaded from http://z3.codeplex.com.
- Lemon Graph Library, it can be downloaded from http://lemon.cs.elte.hu.
- To be able to generate pdf file for the results, pdflatex is required.

4.2 Installation

The MPass Tool can be installed by using the following procedure.

- Copy the MPass_result folder from the MPass directory to your home folder. This is done to make the installation of the MPass tool always consistent irrespective of the location where parent directory is downloaded by the user.

- Using terminal, go to the location of the MPass folder and execute the following commands.

```
$ touch NEWS README AUTHORS ChangeLog
$ autoreconf --force --install
$ ./configure
$ make
$ sudo make install
```

4.3 Installation Options

The configure script is built with GNU autotools, and should accept the usual options and environment variables.

Changing Installation Directory
The command 'sudo make install' will install MPass Tool in the directories which are standard on your system. To override this behaviour add the switch –prefix to the './configure' command:

$ ./configure –prefix=/your/desired/install/path

5 Usage

The MPass Tool can be called from the command line using 'MPass' followed by `Path_to_the_Settings_file` which is expected as the first argument.
By default, it is present in the 'src' folder which is inside the 'MPass directory'.
Thus MPass tool can be called as (if Settings file path is not changed)

```
MPass src/Settings.txt
```

The format of Settings file is as follows:

file	path_to_xml_file
semantics	channel_semantics
bound	bound_for_the_processes
bad	bad_process bad_state
channel_type	type_of_channel

`path_to_xml_file` is path to the xml-files of protocols (message passing programs) present inside the MPass directory. So before calling the MPass tool, change `path_to_xml_file` argument inside the 'Settings.txt' file.
By default, xml-files are present in the 'Includes/Protocols' folder which is inside the 'MPass directory'.

5.1 Description of Settings File

- **file**: It refers to the location of the XML file to be verified.
- **semantics**: It refers to the semantics of the channels. It can be lossy, stuttering or unordered.

- **bound**: It refers to the number of bounds for the automata.
- **bad**: It takes pairs of values. First is the name of the process in which the reachability is to be checked and the second is the set of states for which reachability is being checked.
  NOTE: *Bad state for more one process can also be entered one after the other in the same format as diplayed in the example below.*

  Example:

  ```
  bad SENDER Q0 Q1 RECEIVER INVALID
  bad SENDER Q0 RECEIVER INVALID
  bad RECEIVER INVALID
  ```

- **channel_type**: It refers to the type of channel. It can be :

  `prefix` : For making channels based on the first alphabet of the messages.
  `process`: For making one channel for each process.
  `xml` : For making channels in the same way as specified in the xml file of the protocol.

5.2 Other Optional Arguments

A pdf containing the results of the MPass can also be generated if pdflatex is installed in the system.This can be done using `new` or `old` arguments in addition to the one which we were using before. It can be used as follows :

1. Using the new option:

A new pdf containing the results can be generated using this option. The pdf is placed in the `MPass_result/Result` folder in the home directory. It is used as follows :

```
MPass path_to_settings_file new
```

2. Using the old option:
The result for this run of the MPass is appended to the previously genereated pdf. The pdf is placed in the `MPass_result/Result` folder in the home directory. It is used as follows :

```
MPass path_to_settings_file old
```

References

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