TRAC Tool README

Introduction to TRAC

TRAC is a tool designed to enhance the development and verification of coodination protocols. It focuses on analyzing the well-formedness of DAFSMs, ensuring that only one transition within a group can be satisfied at a time. This tool is instrumental in identifying potential issues early in the development lifecycle, making it a valuable asset for developers and researchers aiming to validate the logical consistency within a protocol. TRAC's flexibility across different operating systems makes.

Docker Installation and Running Instructions

To install and run TRAC using Docker:

1. Pull the Docker image:

   ```
   docker pull loctet/trac_dafsms:v1
   ```

2. Run the container:

   ```
   docker run -it loctet/trac_dafsms:v1
   ```

   This command downloads the TRAC Docker image and starts a container with an interactive terminal.

If Docker is not installed on your system, follow the official Docker installation instructions for Ubuntu at [Docker's official documentation]. This guide provides a comprehensive step-by-step process to get Docker set up and running on your machine.

TRAC can also be cloned directly from its GitHub repository for those who prefer working with the source code. Visit [TRAC's GitHub page] and follow the instructions in the README for setup and usage. This method is ideal for users looking for the latest version or interested in contributing to the project.

Installation Instructions

Before installing TRAC, ensure Python 3.6 or later is installed on your system. TRAC relies on several Python packages for its operation. Use the following pip commands to install the necessary dependencies:

```
pip install z3-solver matplotlib numpy plotly pandas networkx
```

Also make sure the `java JRE` is installed to run the `java` command. This is used to hava a visual view of the DAFSMs

These commands install the Z3 SMT solver, Matplotlib for plotting, and NumPy for numerical computations, which are essential for TRAC's functionality. Ensure all commands are executed successfully to avoid any issues while running TRAC.

Running a Predefined Example: "Simple Market Place"

To run the "simplemarket_place" example with TRAC:

1. **Prepare the Environment**: Ensure TRAC and its dependencies are installed as per the installation instructions.
2. **Navigate to the TRAC Directory**: Open a terminal and change directory to where `cd TRAC/src` is located.
3. **Locate the Example**: The `simplemarket_place` example taken from [Azure repository]() is already within designated examples (`Examples/dafsms_txt/azure`) directory as well as [other Azure blockchain-workbench examples]() namely:
   - [Hello Blockchain]()
   - [Simple Marketplace]()
   - [Basic Provenance]()
   - [Digital Locker]()
   - [Refrigerated Transportation]()
   - [Asset Transfer]()
   - [Room Thermostat]()
   - [Defective Component Counter]()
   - [Frequent Flyer Rewards Calculator]()

   All manually executed examples should be kept in the folder `Examples/dafsms_txt` you can create subdirs, just be assured to give the exact path to the command `Main.py`.
4. **Execute the Example**:
   - Use `Main.py` to run the example. The command syntax is:

     ```
     python3 Main.py --filetype txt "azure/simplemarket_place"
     ```

   - This command tells TRAC to process and verify the "simplemarket_place" example.

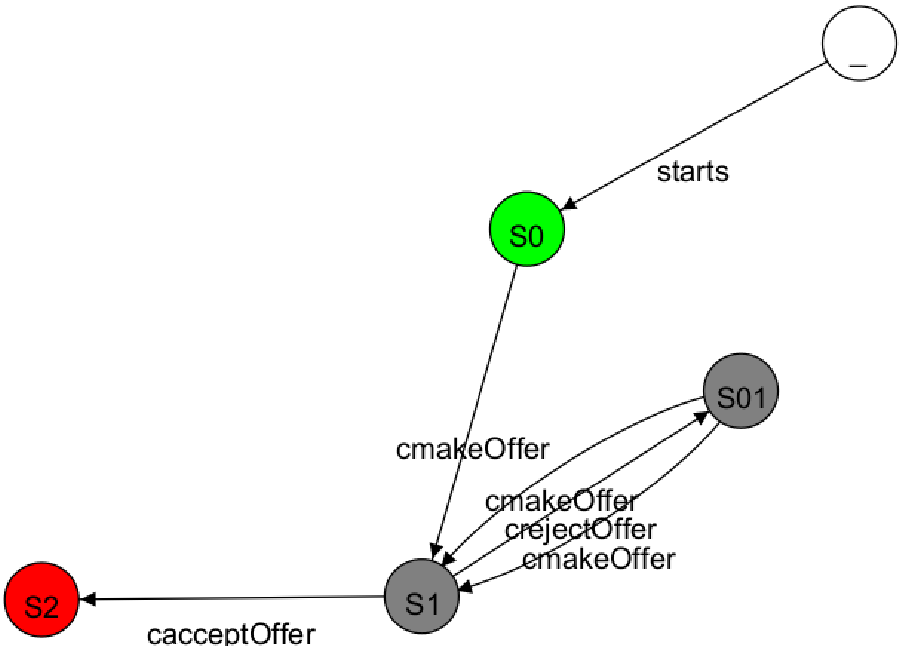
   Follow these steps to successfully run and analyze the "simplemarket_place" example, utilizing TRAC's verification capabilities.
   The result of this should be `(!) Verdict: Well Formed`

   - The structer of DAFSMs is defined in `section 2 of the paper`.
     For the Simplemarket_place example, here is the structure of the TXT file given

   ```
   _ {True} o:O > starts(c,string _description, int _price) {description := _description & price := _price} {string description, int price, int offer} S0
   S0 {_offer > 0} b:B > c.makeOffer(int _offer) {offer := _offer} S1
   S1 {True} o > c.acceptOffer() {} S2+
   S1 {True} o > c.rejectOffer() {} S01
   S01 {_offer > 0} any b:B > c.makeOffer(int _offer) {offer := _offer} S1
   S01 {_offer > 0} b:B > c.makeOffer(int _offer) {offer := _offer} S1
   ```

Deploy transition `starts` the coodinator `c` by passing passing a description and a price these values are assigned to declared `string description` and `int price, int offer`. here the precondition(guard `g`) is `True`.This transition also introduce new participant `o` of role `O`

- `_ {True} o:O > starts(c,string _description, int _price) {description := _description & price := _price} {string description, int price, int offer} S0`
  The next transition `S0 {_offer > 0} b:B > c.makeOffer(int _offer) {offer := _offer} S1` allow new participant `b` of role `B` to make and offer by passing a price `_offer` the guard requires `-offer` to be `>0` to update the value of the state variable `offer` and move the protocol to `S1`
- `S1 {True} o > c.acceptOffer() {} S2+` can be invoque by the previously introduced `o` to accepte the offer and move to a final state `S2` it has the signe `+` after
- `S01 {_offer > 0} any b:B > c.makeOffer(int _offer) {offer := _offer} S1` can be invoke only by any existing participant with role `B`. and `S01 {_offer > 0} b:B > c.makeOffer(int _offer) {offer := _offer} S1` can be invoke only by fresh one. This allow the function `makeOffer` to be available to both `new participant` and `existing ones`



- The result of the check should be `(!) Verdict: Well Formed`

5. **Non Well Formed Examples**
   Let's modify the previous simplemarket place to make it not well-formed.
   `S1 {True} o > c.acceptOffer() {} S2+` to `S1 {True} x > c.acceptOffer() {} S2+`
   now we said x can accept the offer, here, x is never introbuce and therefore the mobel DAFSMs should not be well formed.

   After running the check, we have an error:

```
The Path : _-starts-S0>S0-makeOffer-S1 do not contain the participant x : []
Error from this transitions:S1_acceptOffer()_S2

--For _acceptOffer_0:   Check result ::  False
--- Participants       : False

(!) Verdict: Not Well Formed
```

This tells that the participant `x` has not been intrduced.

Let's do another modification:
`S1 {True} o > c.rejectOffer() {} S01` to `S1 {False} o > c.rejectOffer() {} S01` and `S1 {True} o > c.acceptOffer() {} S01` to `S1 {False} o > c.acceptOffer() {} S01`
Here we are creating a DAFSMs where from `S1` there is no possible out going transition to progress.
The Tool should spot this.
After running the check, we have an error:

```
Error from this transitions:S01_makeOffer(int _offer)_S1

--For _makeOffer_0:   Check result ::  False
--- A-Consistency: False

Simplify of the Not Formula:  Not(And(Not(_offer <= 0), offer == _offer))  ::
True

(!) Verdict: Not Well Formed
```

This tells that the consistency rule is violated with transition `S01_makeOffer(int _offer)_S1` reaching `S1`

6. **Execute the Example**:
   Now that your firt example is completed you can design some DAFSMs and play around with the command by just changing the name of the file in the previous command (`python3 Main.py --filetype txt "xxxxxxxxx"`)

The `Main.py`, can take some configurations as follows:

- `file_name`: Specifies the name of the file (JSON or TXT) to process, without its extension. This is the primary input for TRAC to analyze.
- `check_type`: Optional. Defines the type of check to perform on the input file. It can be one of four options:
  - `1` for Well-Formedness Check,
  - `fsm` for printing the Finite State Machine (FSM). The default is `1`.
- `--filetype`: Optional. Indicates the type of the input file, either `json` or `txt`. The default is `json`.
- `--non_stop`: Optional. Determines the mode of checking, where `1` (default) continues checking even after errors are found, and `2` stops immediately when an error is detected.

- `--time_out`: Optional. Sets a timeout for the operation in seconds. The default is `0`, meaning no timeout.
  This detailed explanation provides a comprehensive guide on how to utilize `Main.py` for different operations within the TRAC tool.

Azure Examples

Example	Line in Code for the feature	How TRAC handle it
Simple Marketplace	ICI : ➖ BI : ✅ L44 PP : ➖ RR : ➖ MRP : ➖	➖ ✅ b:B > c.makeOffer (Line 2 and 6) ➖ ➖ ➖
Hello Blockchain	ICI : ➖ BI : ✅ Line 19 & 31 PP : ➖ RR : ➖ MRP : ➖	➖ ✅ RqT:Resquester, RpD:Responder (Line 1 and 3) ➖ ➖ ➖
Bazaar Item Listing	ICI : ❌ BazaarItem (Line 78) ItemList(Line 40) BI : ✅ BazaarItem (Line 76) ItemList(Line 33) PP : ➖ RR : ➖ MRP : ➖	➖ ➖ ➖ ➖ ➖
Ping Pong Game	ICI : ❌ (Line 18 and 82) BI : ✅ (Line 16 and 67) PP : ➖ RR : ➖ MRP : ➖	➖ ➖ ➖ ➖ ➖
Defective Component Counter	ICI : ➖ BI : ➖ PP : ✅ Line 26 RR : ➖ MRP : ➖	➖ ➖ ✅ m:M (Line 1) ➖ ➖

Example	Line in Code for the feature	How TRAC handle it
Frequent Flyer Rewards Calculator	ICI : ➖ BI : ✅ Line 20 PP : ✅ Line 18 & 21 RR : ➖ MRP : ➖	➖ ✅ ar:AirRep (Line 1) ✅ participant FL f [Line 1] ➖ ➖
Room Thermostat	ICI : ➖ BI : ➖ PP : ✅ Line 16 & 18 & 19 RR : ➖ MRP : ➖	➖ ➖ ✅ participant I i, participant U u (Line 1) ➖ ➖
Asset Transfer	ICI : ➖ BI : ✅ Line 18, PP : ➖ RR : 🔽 Line 97 MRP : ➖	➖ ✅ b:B (Line 3) ➖ 🔽 reject goes to `S01` at that stage if we assume `b` is `new` them it somehow detroy previous `b` as we rebind it to `new B` ➖
Basic Provenance	ICI : ➖ BI : ✅ Line 19 PP : ✅ Line 17 RR : 🔽 Line 51 MRP : ➖	➖ ✅ cp:Conterparty (Line 1) ✅ participant SupplyOwner (Line 1, 2,3) 🔽 Since the protocol does not evove after `S2` (final state) we assume all participants are reintroduced if we restart the protocol ➖
Refrigerated Transportation	ICI : ➖ BI : ✅ Line 32 PP : ✅ Line 28 RR : 🔽 Line 143 MRP : 🔽 Line 119	➖ ✅ o:O (Line 1) ✅ participant D d, participant SC sc, participant OBS obs (Line 1, 5) 🔽 Since the protocol does not evove after `Success` (final state) we assume all participants are reintroduced if we restart the protocol 🔽 This are participants of same role, they are assigne same values

Example	Line in Code for the feature	How TRAC handle it
Digital Locker	ICI : ➖ BI : ✅ Line 21 PP : ✅ Line 19 RR : 🔽 Line 102 MRP : 🔽 Line 76, 91	➖ ✅ o:O (Line 1) ✅ participant Banker ba (Line 1) 🔽 Since `RejectSharingLock` goes back to `S2`, participant `cau` can only invoke function when the new one will be introduce in `S4` 🔽 `AcceptSharingLock` we directly pass the new participant so there is not a role changing but introducing new one

Generating Examples

To generate DAFSM examples with `Generate_examples.py`, follow these steps:

1. **Navigate to TRAC Directory**: Ensure you're in the root directory of TRAC.
2. **Run Generate_examples.py**: Use the command below, adjusting parameters as needed.

```
python3 Generate_examples.py --directory your_directory_name --num_tests 100
```

Replace `your_directory_name` with the desired directory to store test files and adjust `--num_tests` to the number of examples you wish to generate.

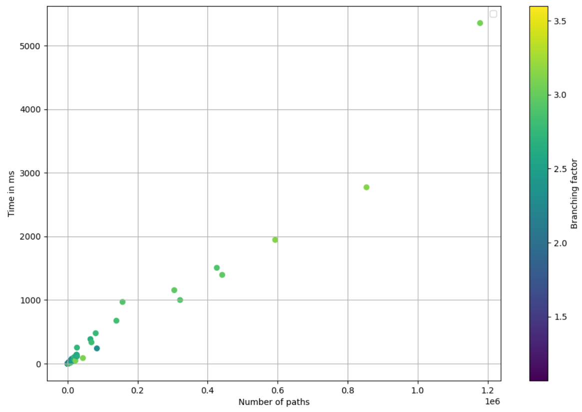
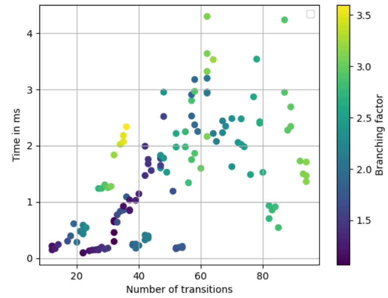
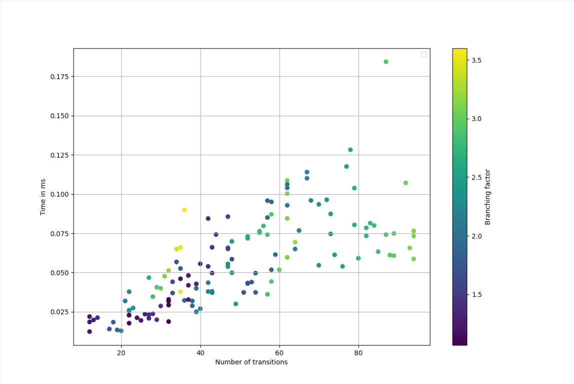
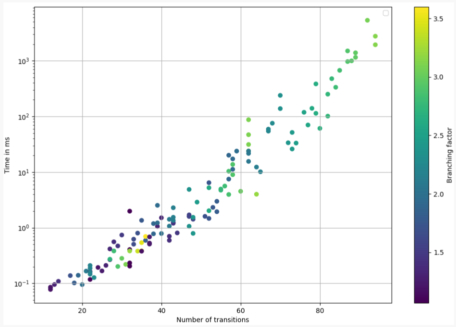
Generate examples of the TRAC tool paper

```
python3 Generate_examples.py --directory examples_1 --steps 5 --
num_example_for_each 5 --num_tests 30 --incremental_gen True
```

This will generate 135 random DAFSMs in the folder `Examples/random_txt/examples_1` with subfolders each folder having 5 tests and a csv file(`list_of_files_info.csv`) containing metadata of those 5 examples. All these csv are then combined into a main csv `list_of_files_info.csv`
This will then run the check and further csv files will be generated and merge (to `merged_list_of_files_info`) when done.
Now you can plot the data to visualize different running time

```
python3 ./plot_data.py examples_1 --file merged_list_of_files_info --field
num_states,num_transitions,num_paths --pl_lines
participants_time,non_determinism_time,a_consistency_time,z3_running_time --
shape 2d --type_plot scatter
```

This will plot these plots

3. **Parameters**:
   The parameters for `Generate_examples.py` enable customization of the DAFSM example generation process. If not specified, values for these parameters are generated randomly:
   - `--directory`: Specifies the directory to save generated examples.
   - `--num_tests`: The number of tests to generate.
   - `--num_states`: The number of states per test.
   - `--num_actions`: The number of actions.
   - `--num_vars`: The number of variables.
   - `--max_num_transitions`: The maximum number of transitions.
   - `--max_branching_factor`: The maximum branching factor.
   - `--num_participants`: The number of participants.
   - `--incremental_gen`: Enables incremental generation.
   - `--merge_only_csv`: Merges results into a single CSV without generating new tests.
   - `--steps`: The increment steps for generating tests.
   - `--num_example_for_each`: The number of examples to generate for each configuration.
4. **Output**: Examples are created in a subdirectory within `Examples/random_txt`. A CSV at the root of this directory contains metadata for each generated example, including paths, number of states, actions, variables, branching factors, and timings.

This process allows for the automated generation and analysis of DAFSM examples, facilitating comprehensive testing and verification of DAFSMs with TRAC.

Running Sets of Examples

To execute multiple examples with `Random_exec.py`, the command format and parameters are as follows:

```
python3 Random_exec.py --directory <subdir> --merge_csv --add_path --
number_test_per_cpu <num> --number_runs_per_each <runs> --time_out <nanoseconds>
```

- `--directory`: Specifies a subdirectory in `Examples/random_txt` where the examples and `list_of_files_info.csv` are located.
- `--merge_csv`: Merges individual CSV results into `merged_list_of_files_info.csv`.
- `--add_path`: Just count the number_path to each test in the CSV.
- `--number_test_per_cpu`: Determines how many tests are run in parallel per CPU.
- `--number_runs_per_each`: Specifies how many times to run each test.
- `--time_out`: Sets a timeout limit for each test.

The process splits tests for parallel execution, outputs results to CSV files, and merges them upon completion. Results are stored in a subdirectory within `Examples/random_txt/<subdir>` to preserve data. Execution time varies with the test suite size.

Plotting Results

To plot results using `Plot_data.py`, follow these command-line instructions, customizing them based on your needs:

```
python3 Plot_data.py <directory> --shape <shape> --file <file_name> --fields
<fields_to_plot> --pl_lines <lines_to_plot> --type_plot <plot_type>
```

- `<directory>`: The directory where the test data CSV is located, relative to `./examples/random_txt/` where the `merged_list_of_files_info.csv` is.
- `--shape`: Choose the plot shape: `2d`, `3d`, or `4d`.
- `--file`: Specify the CSV file name without the extension, defaulting to `merged_list_of_files_info`.
- `--fields`: Set the column(s) to plot against time, default is `num_states`.
- `--pl_lines`: Define which time metric to plot, with defaults including participants time, non-determinism time and a-consistency-time.
- `--type_plot`: Choose the type of 2D plot, with `line` (values `line`, `scatter`, `bar`)as the default.

This command allows for versatile plotting configurations, adjusting for different dimensions and aspects of the data captured in the CSV file. All plots are saved the directory directly.

Main functions

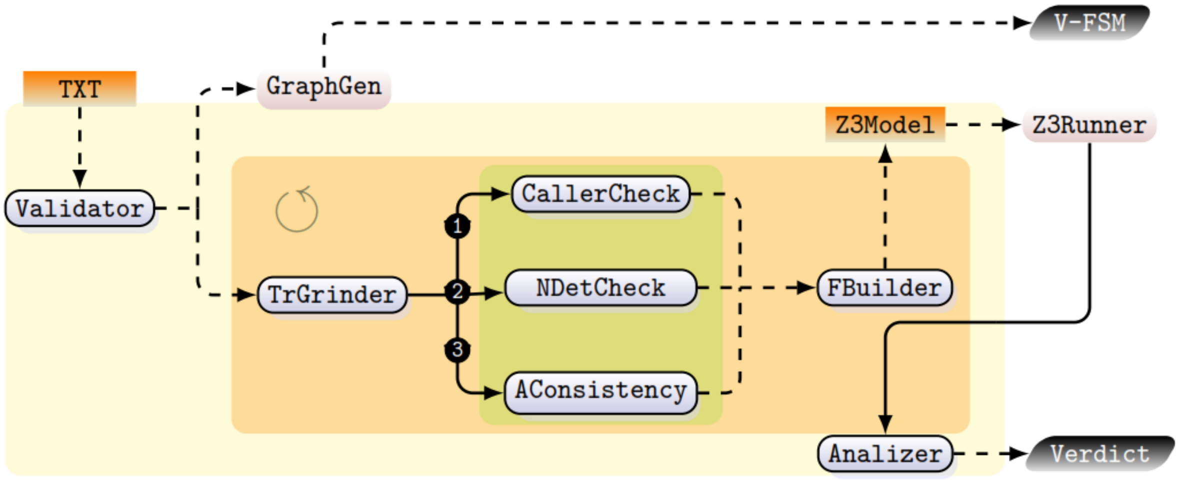


Fig. 1: The architecture of TRAC

- [Validator]()
- [TrGrinder]()
- [CallerCheck]()
- [NDetCheck]()
- [AConsitency]()
- [FBuilder]()
- [Z3Runner]()
- [Analyzer]()

- [Generate Examples]()
- [Run randoms examples]()
- [Plot example]()
- [Defualt Settings]()

The full documentation in html format can be found locally in the subdir `docs`

Reminder

All commands provided, such as running tests, generating examples, executing multiple examples, and plotting results with various scripts like `Main.py`, `Generate_examples.py`, `Random_exec.py`, and `Plot_data.py`, come equipped with a `--help` option. Utilizing `--help` will display detailed usage instructions and available options for each command, aiding users in understanding and effectively utilizing the tool's features.