TECHNISCHE UNIVERSITÄT WIEN

Execution and monitoring of HOA automata with HOAX

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HOA automata

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States: 2
Start: 0
AP: 1 "a"
Acceptance: 1 Inf(0)
Alias: @a 0
--BODY--
State: 0 "s0"
[@a] 0 {0}
[!@a] 1 {0}
State: 1 "s1"
[t] 1
--END--
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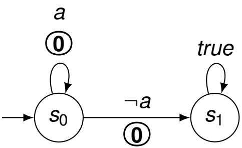

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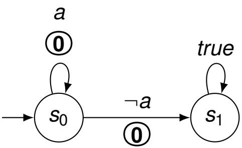

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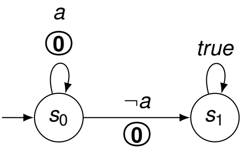

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Tools: Owl, Spin, Spot, Prism, SemML, Strix, AutoHyper . . .

Competitions: SYNTCOMP

HOAX - A HOA eXecutor

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- Configurable input sources for automata inputs (drivers)
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  - (Biased) random variables
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HOAX - A HOA eXecutor

- Execute automaton based on the semantics of HOA
- Configurable input sources for automata inputs (drivers)
  - User input (prompt)
  - (Biased) random variables
  - File-based
- Provide scriptable condition-reaction mechanisms (hooks)
  - If (state reached / trace longer than x / etc.) ...
  - ... Then (reset automaton / print message / etc.)

Basic usage + Sample configuration

Command line

```
$ hoax aut.hoa --config conf.toml
```

conf.toml

```
# Main section (mandatory)
[hoax]
name = "My HOAX config"   # Name for the configuration
version = 1               # Config file version (mandatory)

# Driver for propositions that have none defined
default-driver = "user"   # User prompt (the default)

[[driver.flip]]  # Notice the double brackets
aps = ["a"]      # APs driven by this driver
bias = 0.7       # Bias of "true" (optional, default=0.5)

[[driver.flip]]
# (multiple "flip" drivers may be defined)
aps = ["b", "c"]
```

Hook API example (Python)

- Runner objects track execution of an automaton
- We create Hook objects and append them to Runners

hook_example.py

```python
# Instantiate runner
aut = ...                    # HOA automaton (eg., parsed from file)
conf = DefaultConfig()       # or: conf = TomlConfigV1("config.toml")
run = SingleRunner(aut, conf.driver)

# Instantiate and add hook
condition = Reach(2)         # If state with index=2 is reached...
action = Reset()             # Then reset automaton to initial state
run.add_transition_hook(Hook(condition, action))

# Basic run loop
run.init()
try:
    while True:
        run.step()
except StopRunner:
    pass
```

Monitoring with HOAX

Just a natural application of the tool features

We built Condition classes that turn true iff the run so far is enough to establish that the run will be accepted

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Clearly only some acceptance conditions are actually monitorable. Best effort in general case

Acceptance Conditions in HOA

S = non-empty subset of states (or transitions)

$$\texttt{acc} ::= \mathrm{Inf}(S) \mid \mathrm{Fin}(S) \mid \texttt{acc} \wedge \texttt{acc} \mid \texttt{acc} \vee \texttt{acc}$$

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$\mathrm{Inf}(S)$ Visit at least one element of S infinitely often

$\mathrm{Fin}(S)$ Do not visit any element of S infinitely often

Trap sets

A trap set T of automaton $\mathcal{A}$ is a non-empty subset of its states st. once a run enters T, it may never leave

- Trap sets may be nested
- Minimal trap sets have no nested trap sets
- They correspond to bottom SCCs of $\mathcal{A}$

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We can build a mapping MINTRAPSETOF from each state of $\mathcal{A}$ to the smallest trap set that contains it

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- Indeed, it will return a set of SCCs
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Monitoring by comparing current trap to acceptance set

Example: checking for $\mathrm{Inf}(S)$

Execute this algorithm after every step:

Input : Det. complete automaton $\mathcal{A}$; its current state $q \in Q$
Output: good, bad, ugly, or $\perp$.

Comps $\leftarrow$ MinTrapSetOf(q) # $O(|Q|)$
$T \leftarrow \bigcup Comps$ # $O(|Q|)$
if $T \subseteq S$ **then return** good # $O(|S|)$
if $T \cap S = \emptyset$ **then return** bad # $O(|S|)$
if T is minimal **then**
    if $T \setminus S$ is transient **then return** good **else return** ugly
    # $O(|S| + |E_S|)$ `(sub-graph limited to` S`)`
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- Good prefix $\Leftrightarrow$ the run will be accepted
- Bad prefix $\Leftrightarrow$ the run will be rejected
- X transient $\Leftrightarrow$ every run of $\mathcal{A}$ leaves X infinitely often
- Ugly prefix $\Leftrightarrow$ further monitoring is hopeless

Conclusion

- Configurable tool to execute HOA automata
- Scriptable behaviour through Hooks API
- (Best-effort) monitoring of any acceptance condition

Future work:

- Performance improvements
  - Possibly enabled by Python/cPython evolution
- DSL to script hooks within configuration
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Try HOAX today!

```
$ pipx install hoax
$ uv tool install hoax
```

https://github.com/lou1306/hoax