ROBOSTAR

Fang Yan, Simon Foster, Ibrahim Habli

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Assurance Case Process of RoboChart Supported by Formal Verification

What is an Assurance Case ?

A reasoned and compelling argument, supported by a body of evidence, that a system, service or organisation will operate as intended for a defined application in a defined environment.

Can we produce ACs for RoboChart designs automatically?

YES. Partially. We provide a model-based solution to (i) generate ACs from RoboChart models and (ii) to generate AC evidence with the formal verification capabilities supported by RoboTool.

What's the advantages of the method?

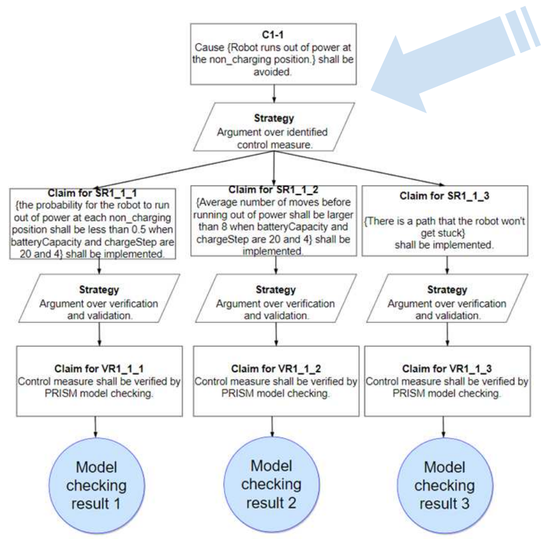
Formal verification has been applied for producing AC evidence, but formal expertise and manual processes are usually involved. We fill the gap between AC claims and the corresponding AC evidence with an **AUTOMATIC** process for RoboChart designs.

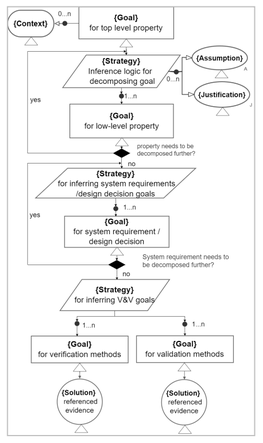
AC Evidence generation by model checking

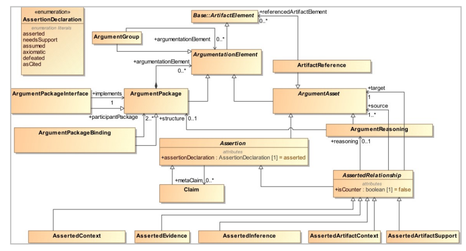
- FDR and PRISM model checking
- Automated RoboChart DSL assertion generation
- Manual input of requirement in structure natural language/template

AC structure and claim generation

- A SACM compliant framework for model-based AC construction from RoboChart models combining the **pattern instantiation** and **model query** methods.



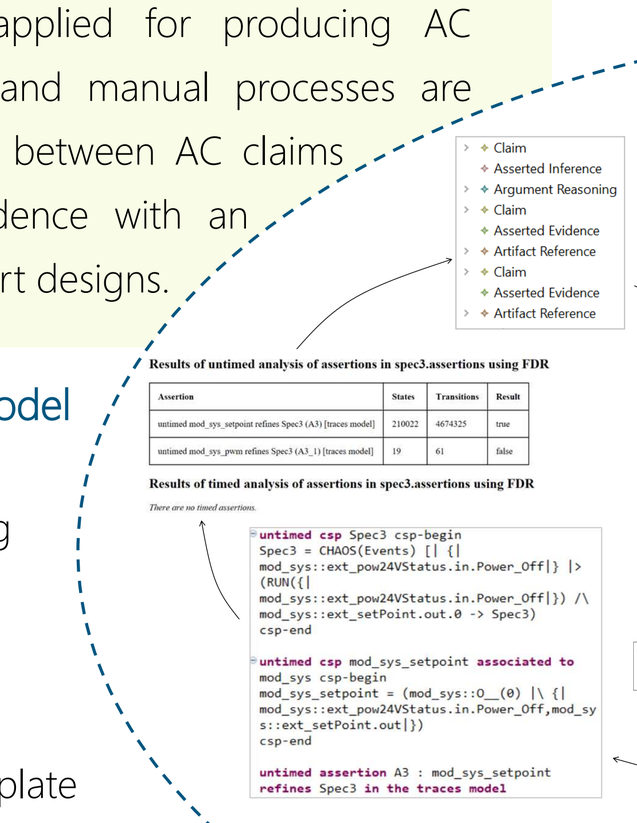


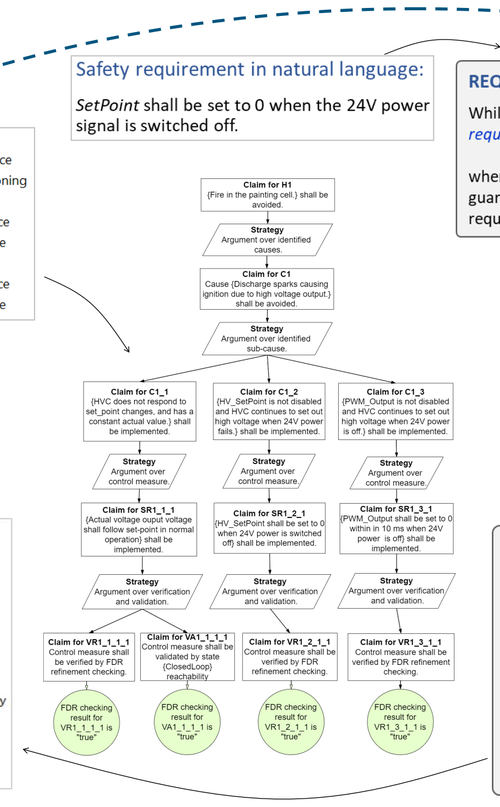


Algorithm 3: Design model query-st/tr

```
1 forall AC.inf ∈ {i | i.source = "Query"} do
2     inf.source.clear
3     forall System.state ∈ {s | s ⊨ Cond1} do
4         state.createClaim&AE
5         inf.Source ← inf.Source ∪ {stateClaim}
6         forall
              System.transition ∈ {tr | tr ⊨ Cond2}
          do
7             tr.createEvidence
8             state.AE.Target ← stateClaim
9             State.AE.Source ←
                  State.AE.Source ∪ {trEvidence}
```

Hazard Log
- Hazardous Situation Robot fails to deliver the mails
  - Cause Robot runs out of power at the non_charging position
    - Control Measure the probability for the robot to run out of power at each non_charging position shall be less than 0.15 when batteryCapacity and chargeStep are 20 and 4
      - Verification PRISM model checking
        - Evidence PRISM model checking results 1
    - Control Measure Average number of moves before running out of power shall be larger than 8 when batteryCapacity and chargeStep are 20 and 4
      - Verification PRISM model checking
        - Evidence PRISM model checking results 2
    - Control Measure There is a path that the robot won't get stuck
      - Verification PRISM model checking
        - Evidence PRISM model checking results 3





Safety requirement in natural language:

SetPoint shall be set to 0 when the 24V power signal is switched off.

REQUIREMENT TEMPLATE CT-2

While (*guard_event*)+ is true,
required_event shall be true.

where
guard_event = *module::event.in/out.value*
required_event = *module::event.in/out.value*

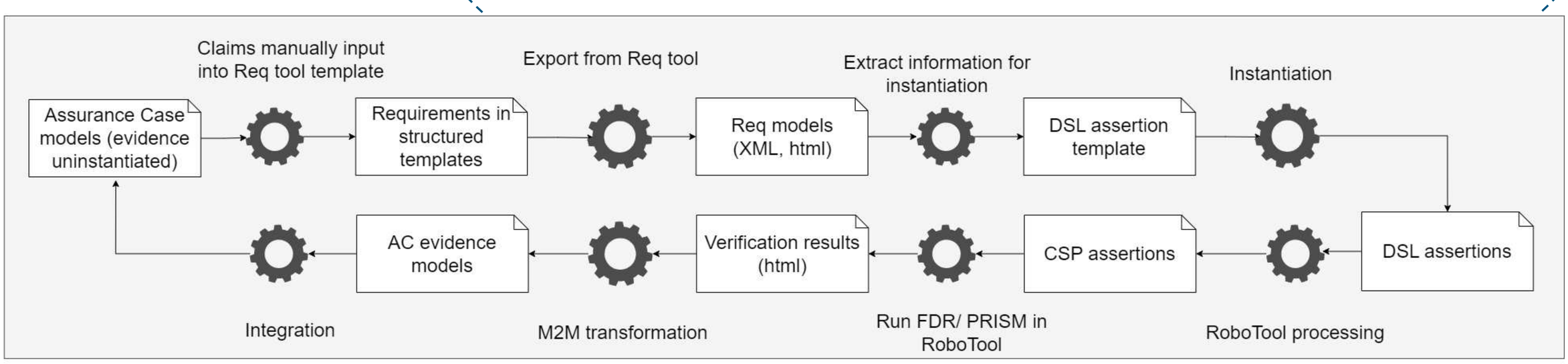
Data flow of a High Voltage Controller example

ASSERTION TEMPLATE AT-5

untimed csp *Spec* csp-begin
Spec = CHAOS(Events) [| {| *guard_event* |} |> (RUN({| *guard_event* |}) /\ *required_event* > *Spec*)
csp-end
untimed csp *Spec*_impl **associated to** *module* csp-begin
*Spec*_impl = *module*::O__(0) |\ {| *guard_event*, *required_event _channel* |}
csp-end
untimed assertion A_*Spec* : *Spec*_impl **refines** *Spec* **in the traces model**

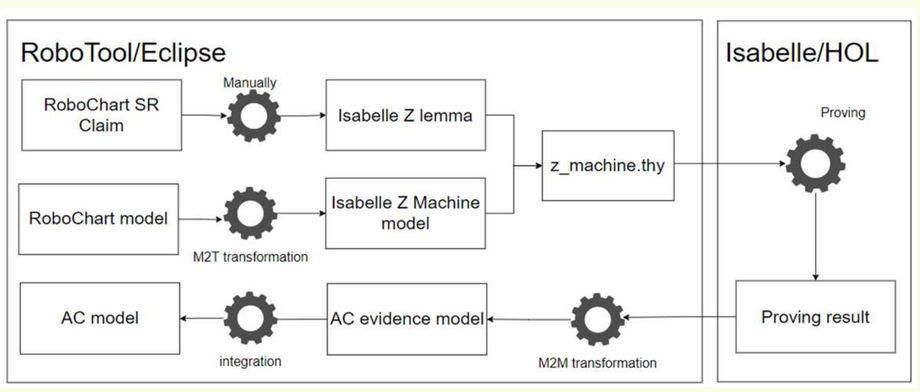
```
While
    signal
    mod_sys::currentState.out.State_ClosedLoop
and signal mod_sys::ext_setPoint.in?x__
is true
  signal
buffered_mod_sys::int_ActualHV.out!x__
shall also be true.
```

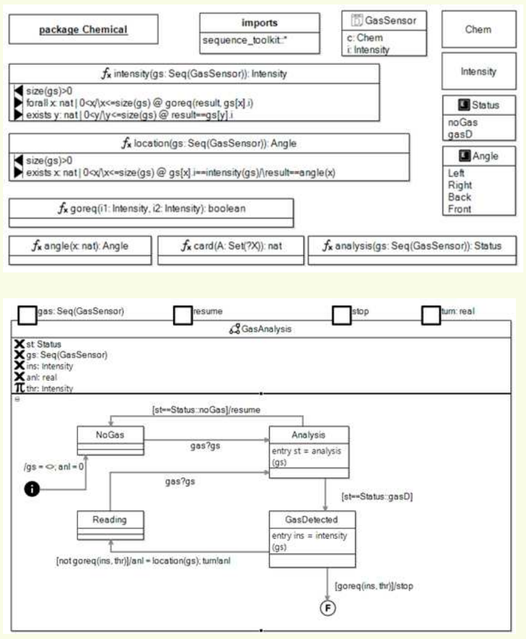
```
<record id="REQ-184.00">
  <title>SetPoint set to 0 when 24V power off</title>
  <status>NO_ERRORS</status>
  <data>
    <template name="while" format="" type="REQUIREMENT">
      <instBlock isUsed="false"/>
      <instBlock isUsed="true">
        <item/>
      </instBlock>
      <instBlock isUsed="false"/>
      <instBlock isUsed="true">
        <item>
          <slot slotId="choiceT4">
            <slotMember class="choice">is true</slotMember>
          </slot>
          <slot slotId="slotT4">
            <slotMember class="keyword">signal </slotMember>
            <slotMember class="signal-
            ref">mod_sys::ext_pow24VStatus.in.Power_Off</slotMember>
          </slot>
        </item>
      </instBlock>
      <instBlock isUsed="false"/>
      <instBlock isUsed="true">
        <item>
          <slot slotId="choiceT2">
            <slotMember class="choice">be true</slotMember>
          </slot>
          <slot slotId="slotT3">
            <slotMember class="keyword">signal </slotMember>
            <slotMember class="signal-
            ref">mod_sys::ext_setPoint.out.0</slotMember>
```



AC Evidence generation by theorem proving

- Automated transformation from RoboChart to formal notation in Isabelle/HOL
- Automated theorem proving (ATP) in Isabelle/HOL
- Manual formalization of AC claims





RoboChart model of Chemical Detector

```
zoperation InitialToReading =
  over GasAnalysis
  pre "act_st= initial"
  update "[ act_st'= Reading
          ,tr'=tr @ [State Reading]
          , desired_st'= {Analysis}
          ]"

zoperation ReadingToAnalysis =
  over GasAnalysis
  params gc"SeqGasSensor"
  pre "act_st= Reading  "
  update "[ act_st'= Analysis
          ,tr'=tr @ [Event  gas, State Analysis]
          , event'= Some gas
          ,st' =analysis(g)
          ,gs' = g
          , desired_st'= {NoGas, GasDetected}
          ]"

zoperation AnalysisToNoGas =
  over GasAnalysis
  pre "act_st= Analysis ∧   st=noGas"
  update "[ act_st'= NoGas
          , event' = Some resume
          ,tr'=tr @ [Event resume, State NoGas]
          , desired_st'= {Reading}
          ]"

zoperation NoGasToReading =
  over GasAnalysis
  pre "act_st= NoGas "
  update "[ act_st'= Reading
          ,tr'=tr @ [ State Reading]
          , desired_st'= {Analysis}
          ]"

zoperation AnalysisToGasDetected =
  over GasAnalysis
  pre "act_st= Analysis ∧ st=gasD"
  update "[ act_st'= GasDetected
          ,tr'=tr @ [State GasDetected]
          ,ins' = intensity(gs)
          , desired_st'= {Reading, final}
          ]"

zoperation GasDetectedToFinal =
  over GasAnalysis
  pre "act_st= GasDetected  ∧ goreq(ins, thr)"
  update "[ act_st'= final
          , event' =Some stop
          ,tr'=tr @ [Event stop, State final]
          , desired_st'= {}
          ]"
```

Operations in Isabelle/HOL representing RoboChart transitions

```
zexpr R1 is
"st=noGas ∧ thr>0 ⟶ (∀ i <(length tr). tr ! i ≠ State final)"

lemma  "InitialToReading() preserves  R1 under GasAnalysis_inv"
  apply zpog_full
  by (metis ProperState.distinct(29) less_SucE nth_append
  nth_append_length tag.inject(1))

lemma  "AnalysisToNoGas() preserves  R1 "
  apply zpog_full
  by (metis One_nat_def ProperState.distinct(18) Suc_eq_plus1
  less_SucE nth_Cons_0 nth_Cons_Suc nth_append nth_append_length
  nth_append_length_plus tag.distinct(1) tag.inject(1))

lemma  "AnalysisToGasDetected()   preserves  R1"
  by (zpog_full; auto)

lemma "GasDetectedToFinal() preserves R1 under GasAnalysis_inv"
  by zpog_full

lemma  "NoGasToReading() preserves R1"
  apply zpog_full
  by (simp add: nth_append)

lemma  "GasDetectedToReading() preserves   R1 "
  apply zpog_full
  by (metis One_nat_def ProperState.distinct(30) Suc_eq_plus1
  less_SucE nth_Cons_0 nth_Cons_Suc nth_append nth_append_length
  nth_append_length_plus tag.distinct(1) tag.inject(1))
```

Claim formalization and verification through ATP in Isabelle/HOL for each operation

robostar.cs.york.ac.uk

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