COMBINING FEATURE ANNOTATIONS AND SUPERIMPOSITION IN FORMAL MODELING

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Annotative and Compositional Approaches
for implementing features

Annotative

- **Mark fragments** of feature-specific code
- Derive variant using **projection**
- Examples:
  - `#ifdef`
  - Featured Transition Systems
- Arbitrary **granularity**, construction of **family-model** straightforward
- Modularization difficult, poor traceability

Compositional

- Implement features as distinct **modules**
- Create variant using **composition**
- Examples:
  - Jak
  - fSMV
- Feature **modularity**, easy separation of concerns
- Limited granularity, construction of family model challenging

Goal: Combine **annotative** and **compositional** approaches in **formal modeling** to enable:

- **Fine-grained** modifications
- Feature **modularization**
- **Family-based analysis** and dynamic reconfiguration

Formal Behavioral Modeling
using guarded commands

$$[action]\ f\text{-}guard \wedge guard \rightarrow update$$

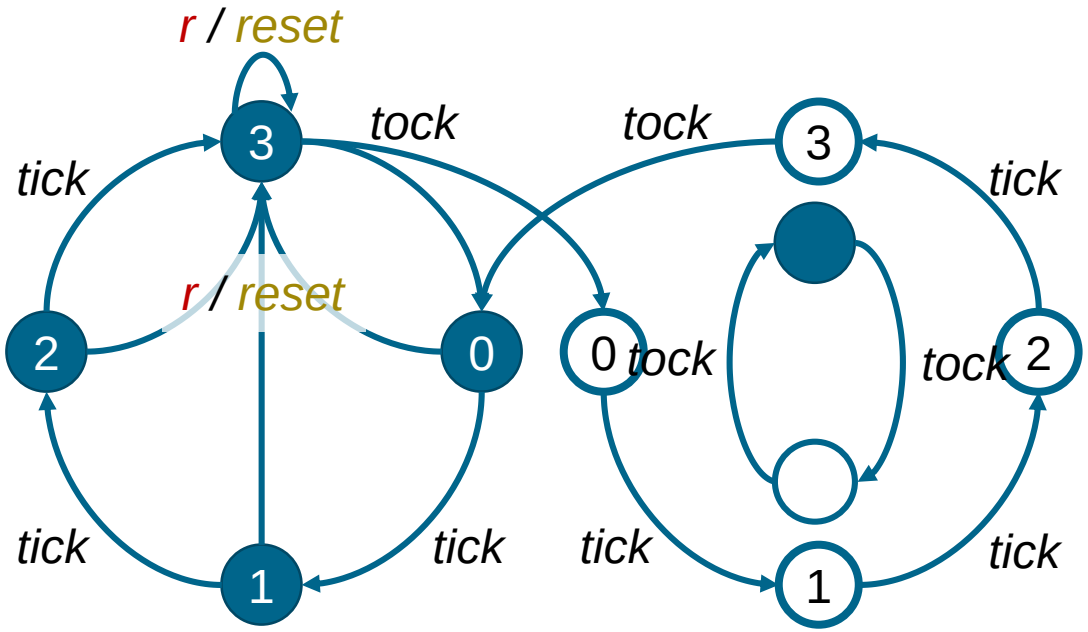
- Boolean condition over features
- Boolean condition over variables
- Variable updates

Example: 2-bit counter

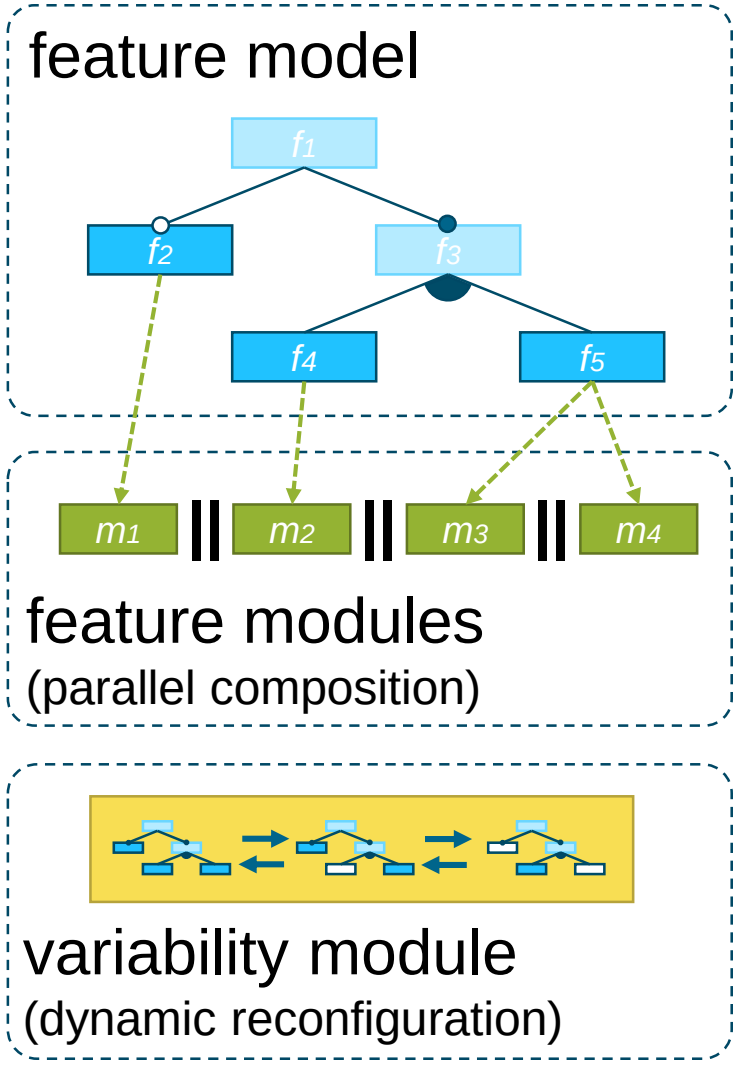
P_1:
[*tick*] $(c < 3) \rightarrow (c' = c + 1)$
[*tock*] $(c = 3) \rightarrow (c' = 0)$
[*reset*] $r \wedge tt \rightarrow (c' = 0)$

P_2:
[*tock*] $tt \rightarrow (b' = \neg b)$

$P_1 \parallel P_2$:
[*tick*] $(c < 3) \rightarrow (c' = c + 1)$
[*tock*] $tt \wedge (c = 3) \rightarrow (c' = 0) \wedge (b' = \neg b)$



The ProFeat Language
annotative feature-oriented modeling




```
[step] (active(executive) & num_floorreq(top)>0
  ? ( cabin_pos=top ? 1 : 0)
  : ( active(ttf) & (load/size > 2/3)
      ? num_cabinreq(k)
      : num_cabinreq(k) + num_floorreq(k)
    )) > 0 |
    !(active(overload) => (load <= size)) |
    !(active(parking) & idleing => !(cabin_pos=eg))
    -> (cabin_open' = true);
```

P. Chrszon, C. Dubslaff, S. Klüppelholz, C. Baier: “ProFeat: Feature-oriented Engineering for Family-based Probabilistic Model Checking”, Formal Aspects of Computing, Vol. 30, No. 1, pp. 45-74, 2018.

Composition by Superimposition
modifying guarded commands using delta programs

- **Superimposition** describes how a system or module is **modified** upon **composition**
- **Extension** by adding commands to module
- **Modification** and removal via modification function:

$$m : Cmd \rightarrow 2^{Cmd}$$

- Example: saturating counter

P_1:
[*tick*] $(c < 3) \rightarrow (c' = c + 1)$
[*tock*] $(c = 3) \rightarrow (c' = 0)$

Δ:
m(“[*tock*] $(c = 3) \rightarrow (c' = 0)$”) = “[*tick*] $(c = 3) \rightarrow$ true”

- **Combination** of superimposition and annotative approach by allowing annotations in feature modules and deltas

Clemens Dubslaff: “Compositional Feature-Oriented Systems“, Software Engineering and Formal Methods (SEFM), 2019.
Clemens Dubslaff: “Quantitative Analysis of Configurable and Reconfigurable Systems”, PhD thesis, TU Dresden, 2022.

Combining Feature Annotations and Superimposition in the ProFeat language

```
feature Elevator
  module cabin
    pos : [0..5] init 0;
    dir : {UP, DOWN} init UP;
    door : {CLOSED, OPEN} init CLOSED;

    [tick] door = CLOSED & dir = UP & req_above ->
      (pos' = pos + 1) & (dir' = if pos = 4 then DOWN else UP);
    [tick] door = CLOSED & dir = DOWN & req_below ->
      (pos' = pos - 1) & (dir' = if pos = 1 then UP else DOWN);
  endmodule
endfeature

feature Parking
  change module Elevator.cabin
     rewrite floor_buttons[0] to
     (if !active(Executive) & num_req_total = 0 then true else floor_buttons[0]);
  endmodule
endfeature
```


M. Plath, M. Ryan: “Feature Integration using a Feature Construct”, Sci. Comp. Program. 41-1, pp. 53-84, 2001.

Discussion
design decisions and open questions

- Unify or distinguish the **two kinds** of feature modules?
  1. Adding new parallel modules
  2. Modify existing parallel modules using superimposition
- Implicit or explicit **interfaces** (variables, actions) in delta modules?
- Superimposition is **order-dependent**, how is this resolved?
  - Derive from dependency graph?
  - Derive from feature model?
  - Explicit definition?
- Interaction between **rewrites and function calls**: Should rewrites enter function bodies?

Impressum

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