Lifting Verification Results for Preemption Statements

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Outline

1. Introduction
   - Motivation
   - Synchronous Model of Computation
   - Preemption Behavior
2. Lifting Verification Results for Preemption Statements
   - Abort Transformation
   - Suspend Transformation
3. Conclusion

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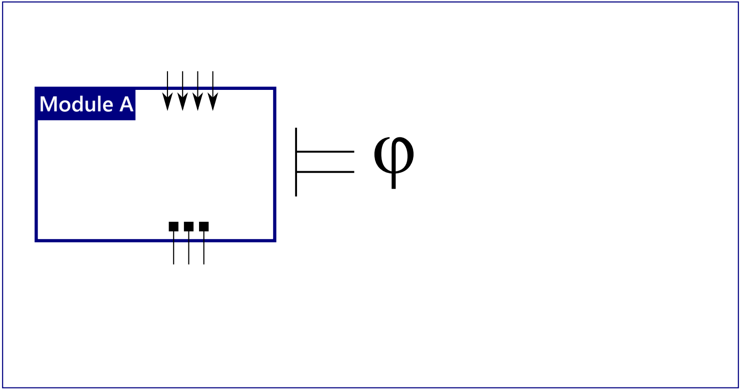
Motivation

interactive proof rules for module calls in synchronous programs



Motivation

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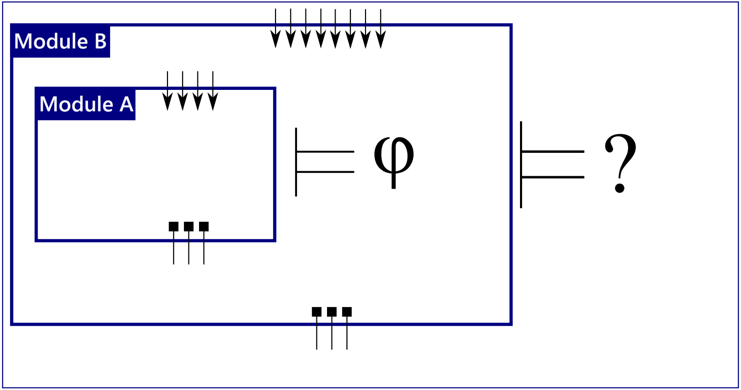
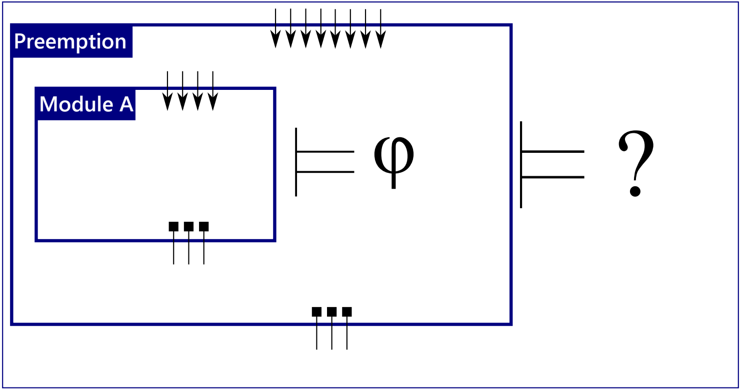


What is this talk about?



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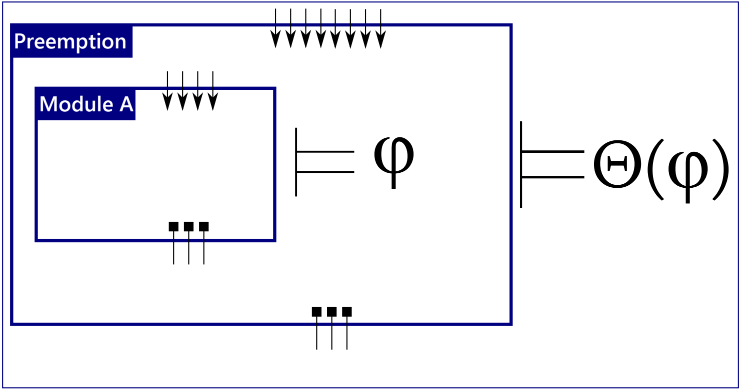
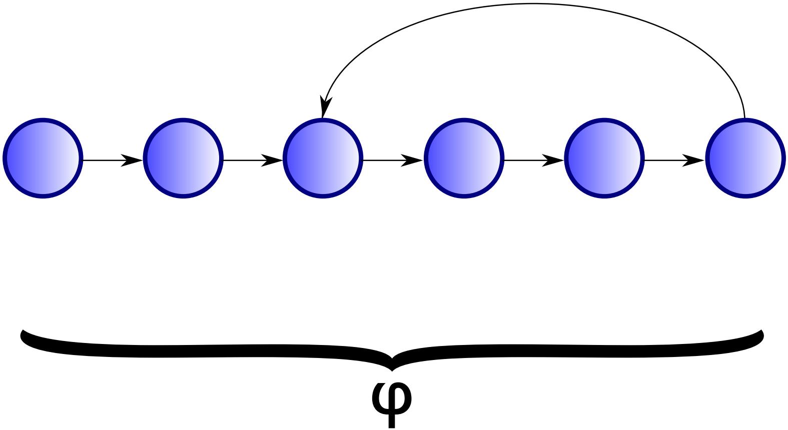


Influence of Preemption on Modules



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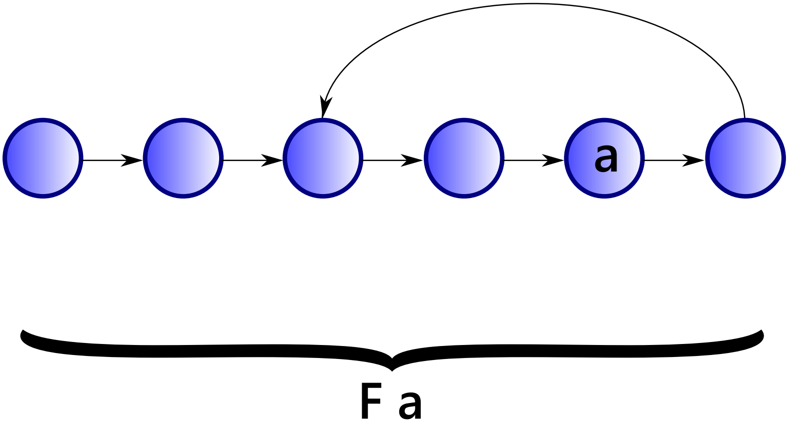
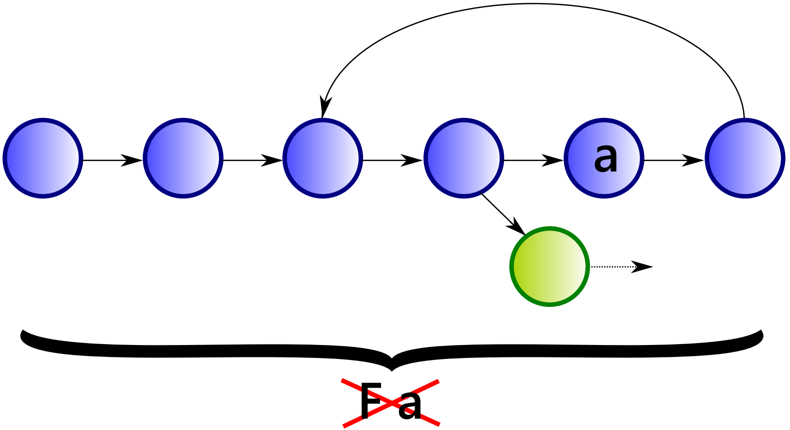


Influence of Preemption on Modules



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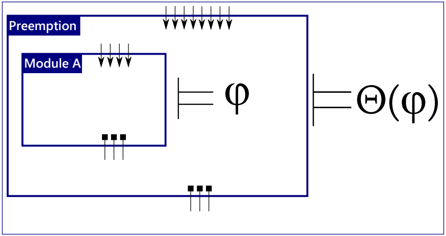

Approach

- restriction to preemption specific behavior
- step wise application possible
- preemption-specific Θ
- specification should preserved 'as much as possible'
- correct by construction

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Synchronous Model of Computation

- execution is divided into a sequence of reactions steps
- behavior in a reaction step
  - starts/ends in a **pause**
  - all inputs are read
  - all outputs are produced (instantaneously)
  - new internal state is determined
  - each variable has a unique value

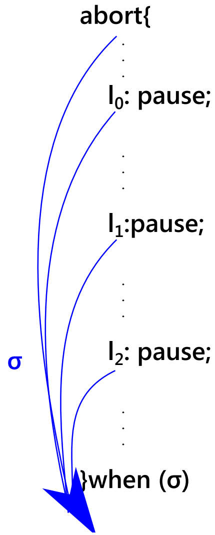
Outline

Example

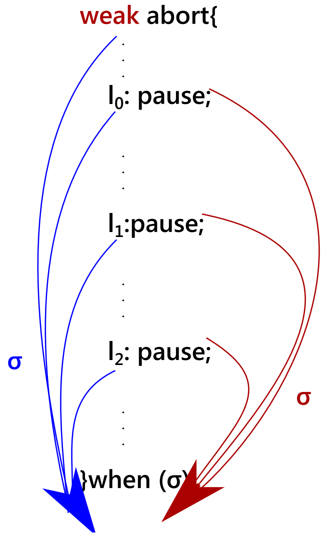
`abort` behavior

- execution of nested program part is stopped

Example



Example

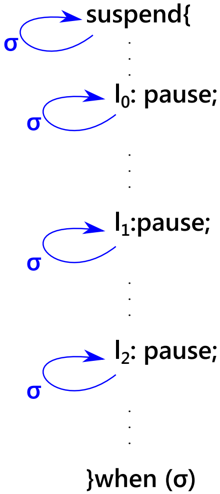


Example

suspend behavior

- execution of nested program part is (infinitely) postponed

Example



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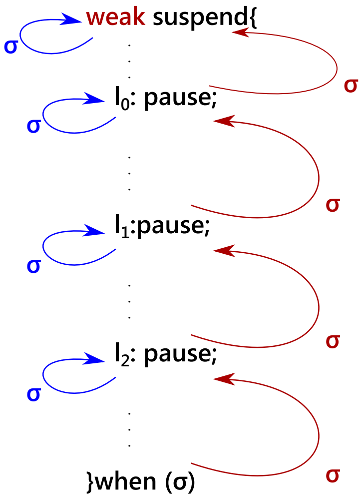

Outline

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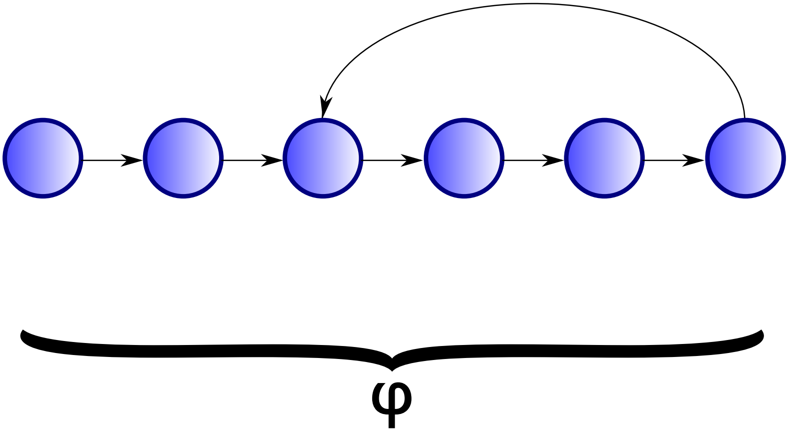
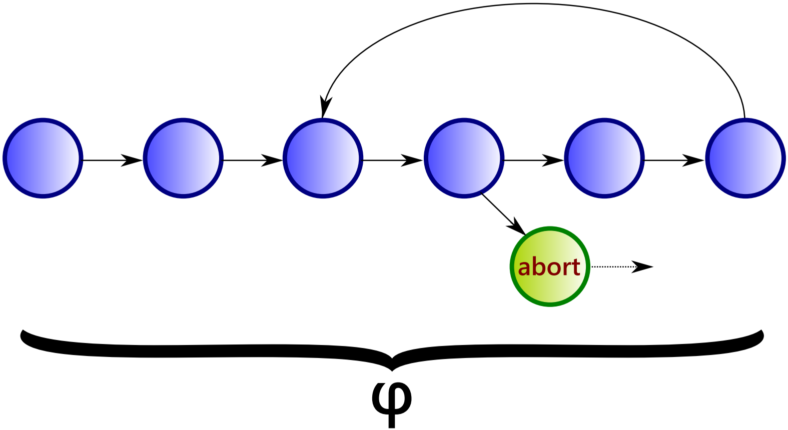
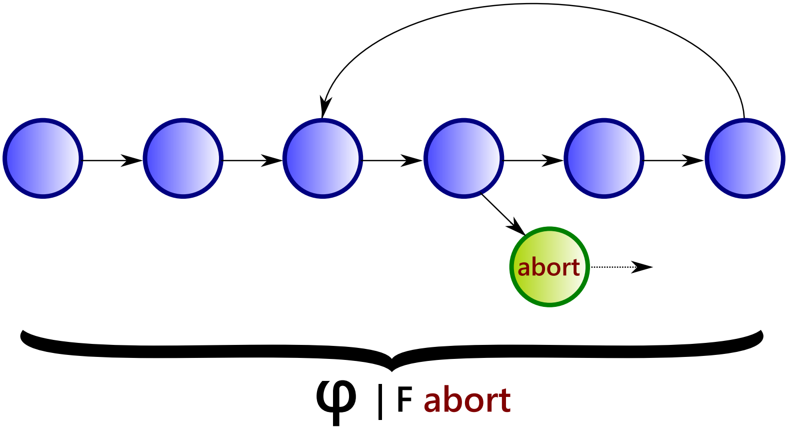
Idea

- **abort** stops execution
- preemptive specification preserves 'as much as possible'
- preemptive specification $\Theta^{st}_{ab}(\varphi)$ for φ is satisfied
  - φ already satisfied
  - abortion in a state not violating φ


φ


abort
φ

Naive Transformation #1 (too weak)



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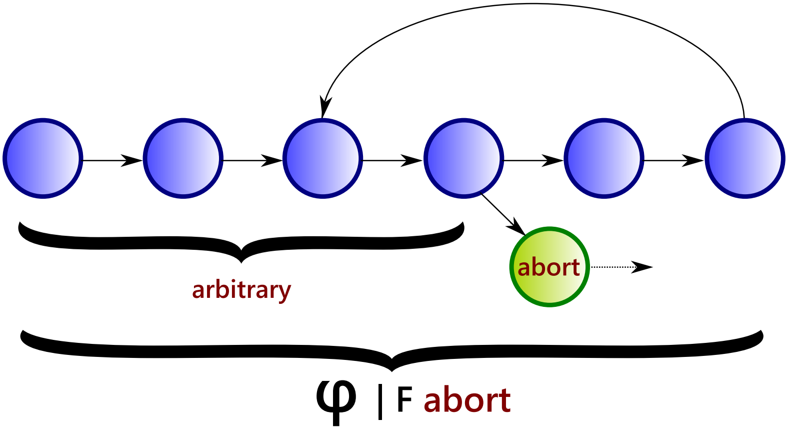

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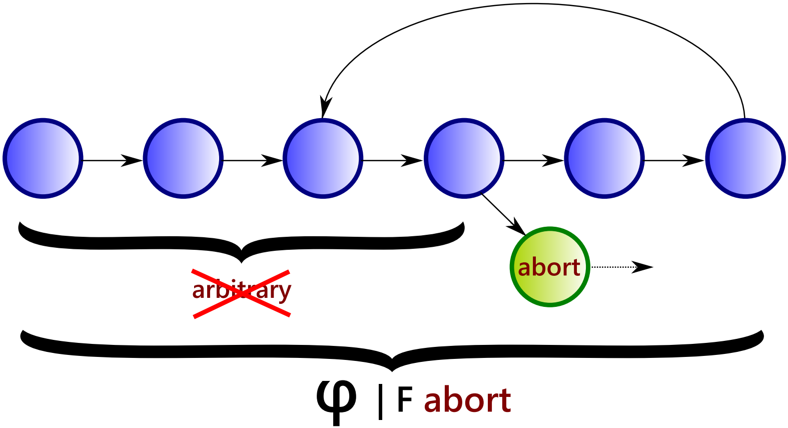
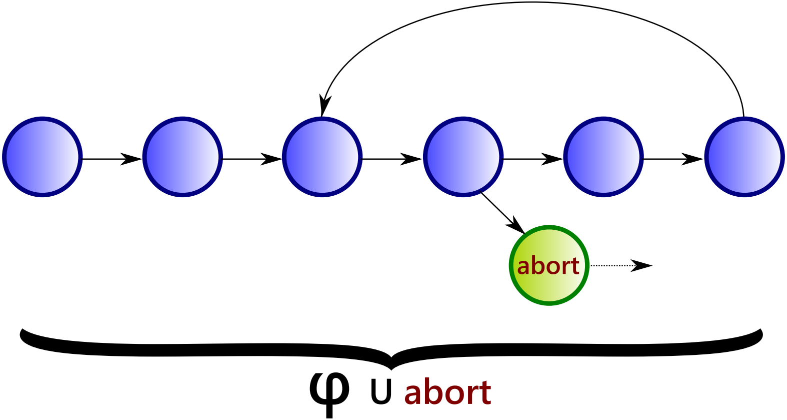


Naive Transformation #2 (too strong)



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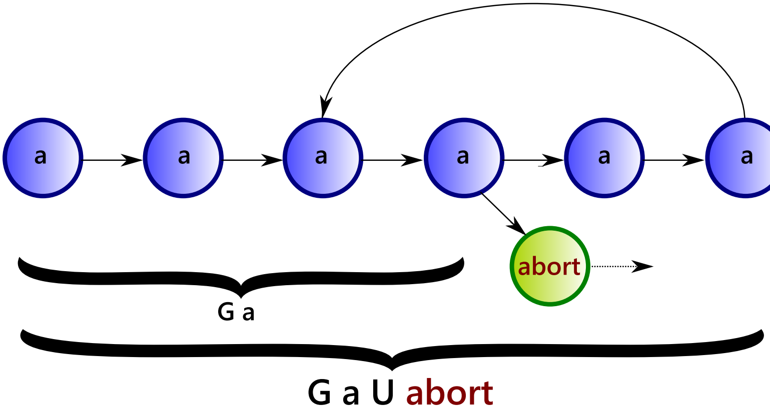

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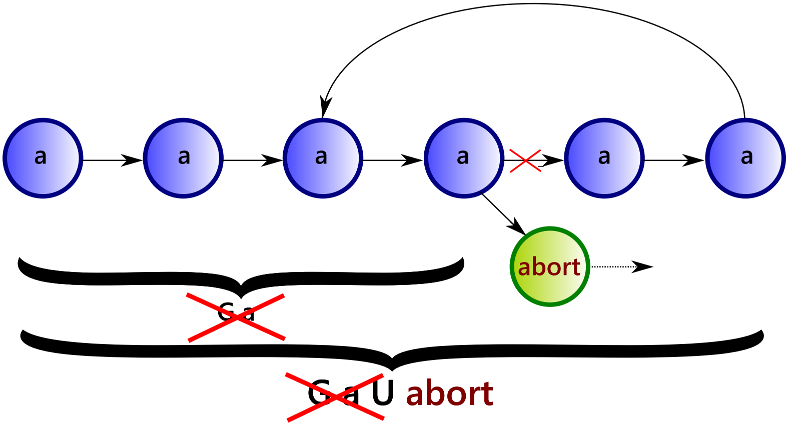


Correct Transformation for Abort

Transformation $\Theta^{st}_{ab}(\varphi, \sigma)$

The transformation $\Theta^{st}_{ab}(\varphi, \sigma)$ that generates an **abort**-sensitive specification for $A\varphi$ given in NNF is defined recursively as

$$\Theta^{st}_{ab}(\varphi, \sigma) := \begin{cases} \sigma \vee \varphi, & \text{if } \varphi \text{ is propositional} \\ \sigma \vee \mathbf{X}(\Theta^{st}_{ab}(\psi, \sigma)), & \text{if } \varphi = \mathbf{X}\psi \\ \Theta^{st}_{ab}(\psi, \sigma) \otimes \Theta^{st}_{ab}(\gamma, \sigma), & \text{if } \varphi = \psi \otimes \gamma \text{ with} \\ & \otimes \in \{\underline{\mathsf{U}}, \mathsf{U}, \wedge, \vee\}. \end{cases}$$

Examples

$$\begin{array}{lclclcl} \Theta^{st}_{ab}(\mathsf{Xa}, \sigma) & \equiv & \sigma \vee \Theta^{st}_{ab}(\mathsf{Xa}, \sigma) & \equiv & \sigma \vee \mathsf{X}(\sigma \vee \mathsf{a}) & & \\ \Theta^{st}_{ab}(\mathsf{Ga}, \sigma) & \equiv & \Theta^{st}_{ab}([\mathsf{a}\ \mathsf{U}\ 0], \sigma) & \equiv & [(\sigma \vee \mathsf{a})\ \mathsf{U}\ \sigma] & \equiv & [\mathsf{a}\ \mathsf{U}\ \sigma] \\ \Theta^{st}_{ab}(\mathsf{Fa}, \sigma) & \equiv & \Theta^{st}_{ab}([1\ \underline{\mathsf{U}}\ \mathsf{a}], \sigma) & \equiv & [1\ \underline{\mathsf{U}}\ (\mathsf{a} \vee \sigma)] & \equiv & \mathsf{F}(\mathsf{a} \vee \sigma) \end{array}$$

Interactive Proof Rule

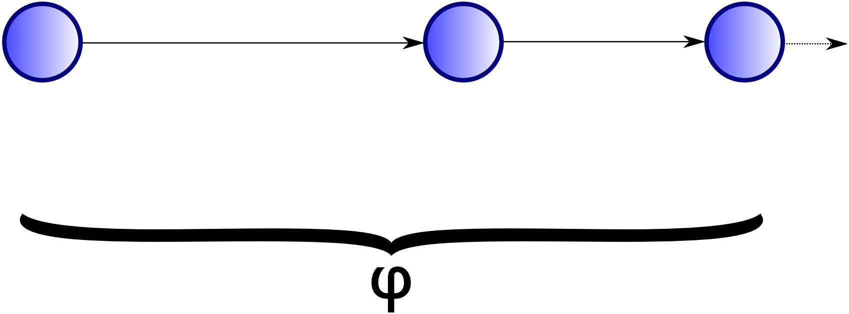
$$\frac{M \models \varphi}{\texttt{\textbf{abort}}\{\texttt{M}\}\texttt{\textbf{when}}(\sigma) \models \Theta^{\mathsf{st}}_{\mathsf{ab}}(\varphi, \sigma)}$$

Outline

Idea

- **suspend** postpones execution
- preemptive specification $\Theta^{\mathrm{st}}_{\mathrm{sp}}(\varphi)$ for φ is satisfied
  - ignoring suspended states satisfies φ
  - possibility of infinite suspension

Idea for Suspend



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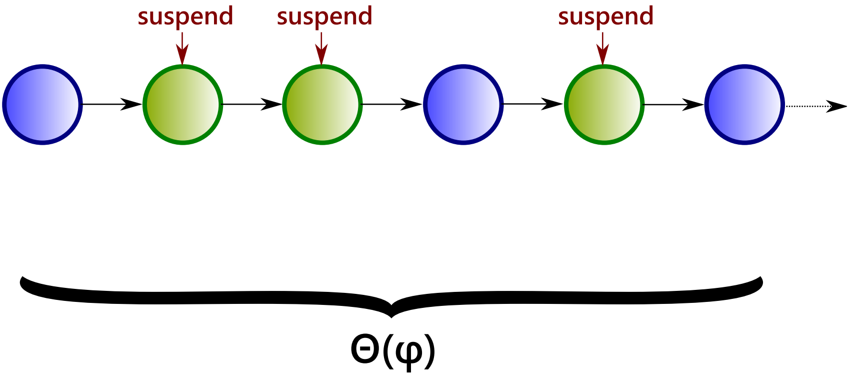

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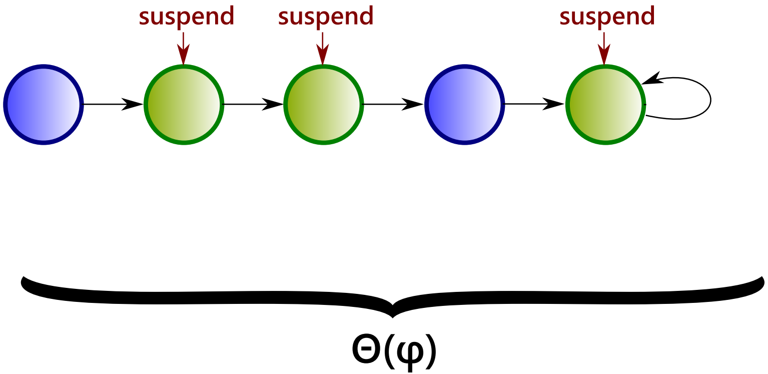


Correct Transformation for Suspend

Transformation $\Theta_{sp}^{st}(\varphi, \sigma)$

For a given specification $\mathsf{A}\varphi$, the transformation $\Theta_{sp}^{st}(\varphi, \sigma)$ is defined as

$$\Theta_{sp}^{st}(\varphi,\sigma) := \begin{cases} [\varphi \ \mathsf{W} \ \neg\sigma], & \text{if } \varphi \text{ is propositional} \\ \left[(\mathbf{X}\Theta_{sp}^{st}(\psi,\sigma)) \ \mathsf{W} \ \neg\sigma\right], & \text{if } \varphi = \mathbf{X}\psi \\ \Theta_{sp}^{st}(\psi,\sigma) \otimes \Theta_{sp}^{st}(\gamma,\sigma), & \text{if } \varphi = \psi \otimes \gamma \text{ with} \\ & \otimes \in \{\underline{\mathsf{U}}, \mathsf{U}, \wedge, \vee\}. \end{cases}$$

Examples

$$\begin{aligned} \Theta_{sp}^{st}(\mathsf{Xa},\sigma) &\equiv \left[(\mathsf{X}\Theta_{sp}^{st}(\mathsf{a},\sigma)) \ \mathsf{W} \ \neg\sigma\right] \equiv [(\mathsf{X}\,[\mathsf{a} \ \mathsf{W} \ \neg\sigma]) \ \mathsf{W} \ \neg\sigma] \\ \Theta_{sp}^{st}(\mathsf{Ga},\sigma) &\equiv \Theta_{sp}^{st}([\mathsf{a} \ \mathsf{U} \ 0],\sigma) \equiv [[\mathsf{a} \ \mathsf{W} \ \neg\sigma] \ \mathsf{U} \ 0] \equiv \mathsf{G}\,[\mathsf{a} \ \mathsf{W} \ \neg\sigma] \\ \Theta_{sp}^{st}(\mathsf{Fa},\sigma) &\equiv \Theta_{sp}^{st}([1 \ \underline{\mathsf{U}} \ \mathsf{a}],\sigma) \equiv [1 \ \underline{\mathsf{U}} \ [\mathsf{a} \ \mathsf{W} \ \neg\sigma]] \equiv \mathsf{F}\,[\mathsf{a} \ \mathsf{W} \ \neg\sigma] \end{aligned}$$

Interactive Proof Rule

$$\frac{M \models \varphi}{\textbf{suspend}\{\texttt{M}\}\textbf{when}(\sigma) \models \Theta_{\mathsf{sp}}^{\mathsf{st}}(\varphi, \sigma)}$$

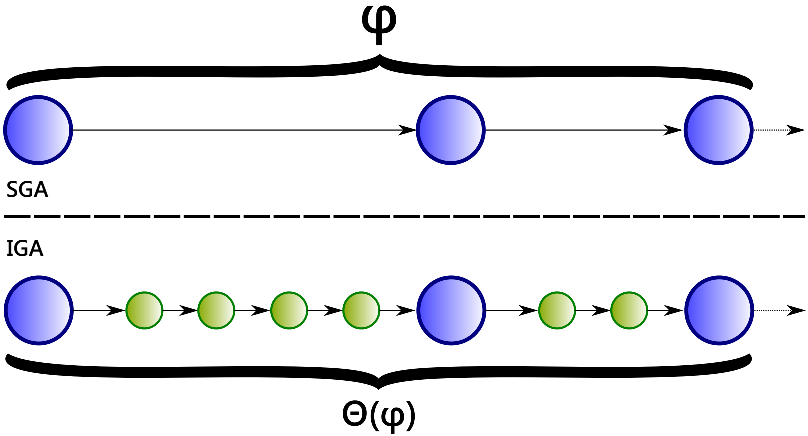
Outline

Summary

- synchronous model of computation
- preemption behavior
- reuse of verification results in a preemption context
- automatic and correct-by-construction transformation

Application of Suspend Transformation

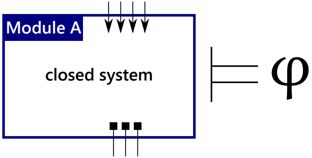
- Clock refinement
- Translation from synchronous to interleaved guarded actions



The End

Questions?

Already Published Approach



[GeSc13a]

M. Gesell and K. Schneider
Modular Verification of Synchronous Programs, ACSD 2013

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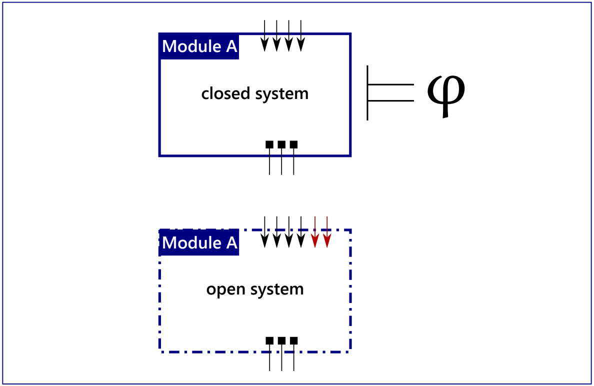

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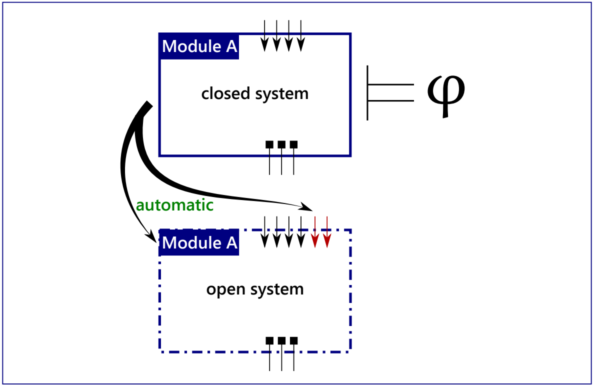

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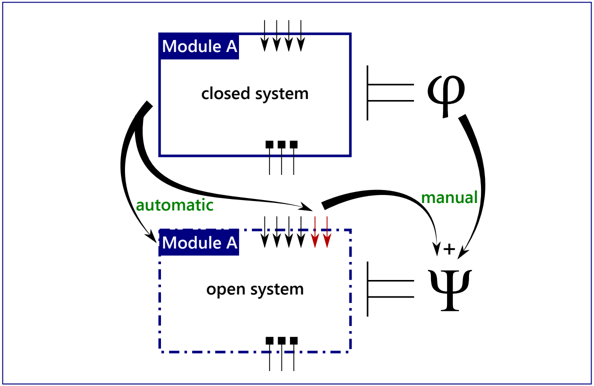

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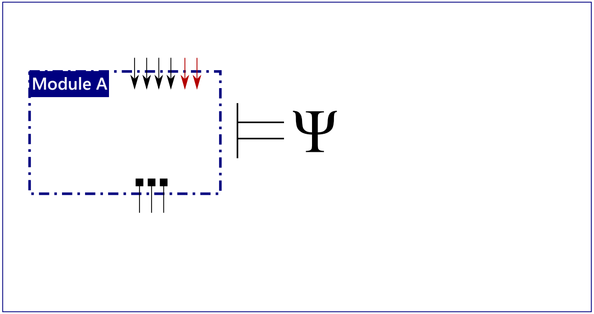

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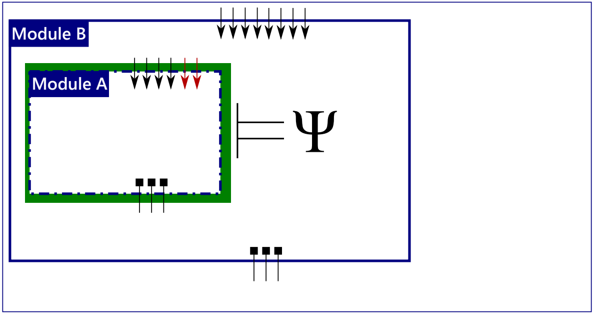

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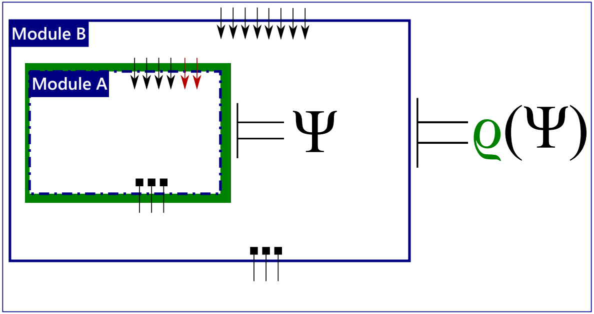
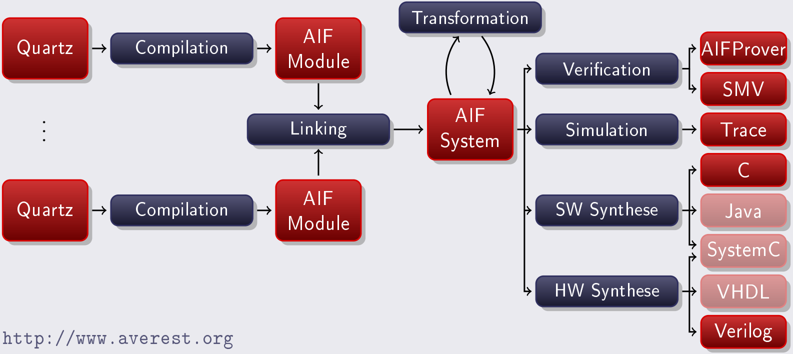


Advantages and Disadvantages

+ reuse of verification results
– manual transition step
– additional verification task
○ no necessary relation to the original specification

Averest Design Flow



http://www.averest.org