SEALS: A framework for building Self-Adaptive Virtual Machines

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Context

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Challenge : provide functionality for self-adaptation in DSLs

[1] Cf. `https://waymo.com`, `https://www.netflix.com`

Contribution overview

The SEALS Framework supports the definition of . . .

1. Language abstract syntax and **semantics**
2. Correctness envelope defining the valid semantics for a domain concept
3. The feedback loop and associated trade-off reasoning
4. Adaptations and the predictive model of their impact on the trade-off

What are Self-Adaptable Virtual Machines

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- A specific case of Self-Adaptable Languages [1]
- Reification of a **feedback loop** [2] in language **operational semantics**

[1] G. Jouneaux, O. Barais, B. Combemale, *et al.*, "Towards Self-Adaptable Languages," in *Onward! 2021*, Chicago, United States, Oct. 2021. [Online]. Available: `https://hal.inria.fr/hal-03318816`

[2] IBM, "An architectural blueprint for autonomic computing," *IBM White Paper*, vol. 31, 2006

What are Self-Adaptable Virtual Machines

- A specific case of Self-Adaptable Languages [1]
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Additionally, in our case :

- Pluggable architecture for adaptations
- Delegation of configuration responsibilities

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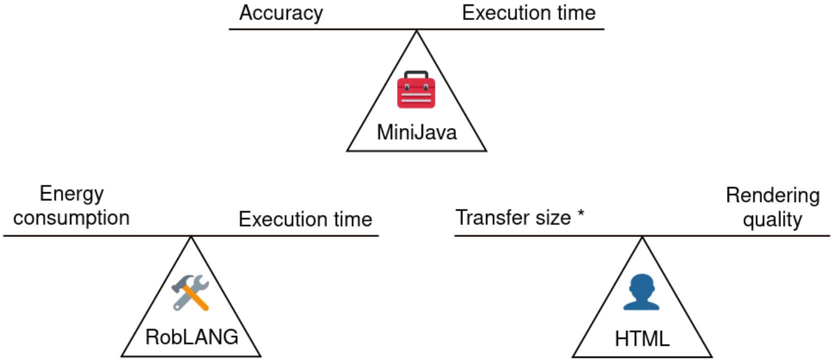
Motivating Examples



Accuracy

Execution time

MiniJava

Energy consumption

Execution time

RobLANG

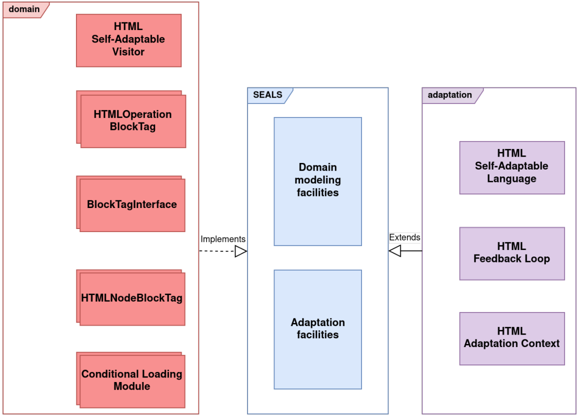
Transfer size *

Rendering quality

HTML

* Transfer size is proportional to energy consumption (Cf. `https://www.websitecarbon.com/`)

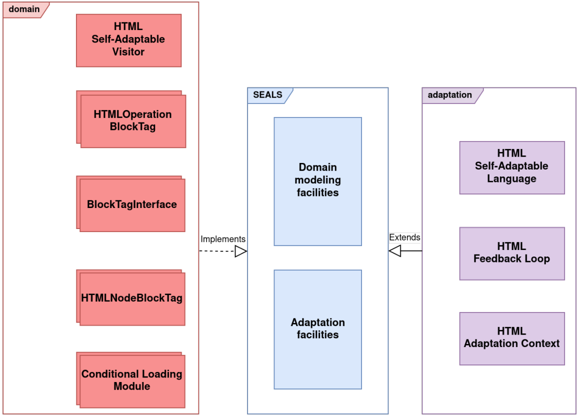
Approach overview



Approach overview on the HTML use case

Approach overview

- Concepts provided by SEALS



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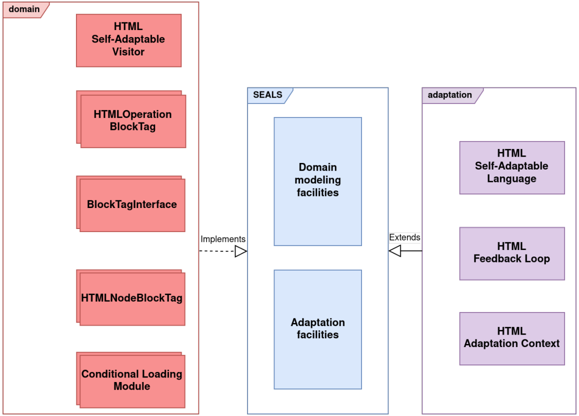
- Concepts provided by SEALS
- Modeling of domain concepts



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- Concepts provided by SEALS
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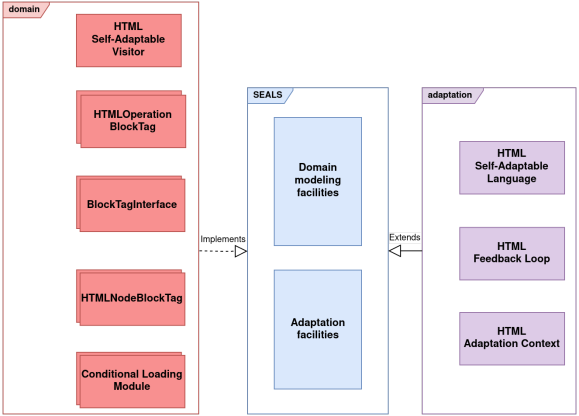
- The specialized adaptation process



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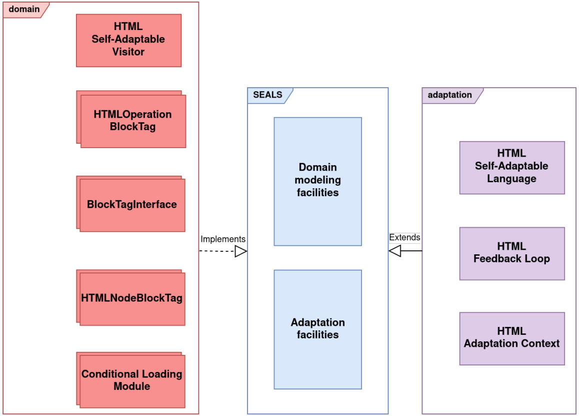
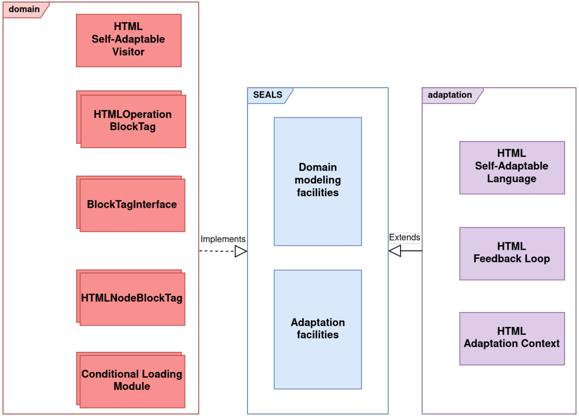
Modeling of domain concepts



Approach overview on the HTML use case

Modeling of domain concepts

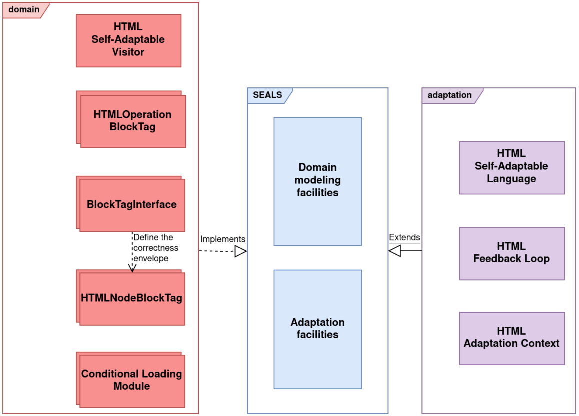
1. Define the abstract syntax



Approach overview on the HTML use case

Modeling of domain concepts

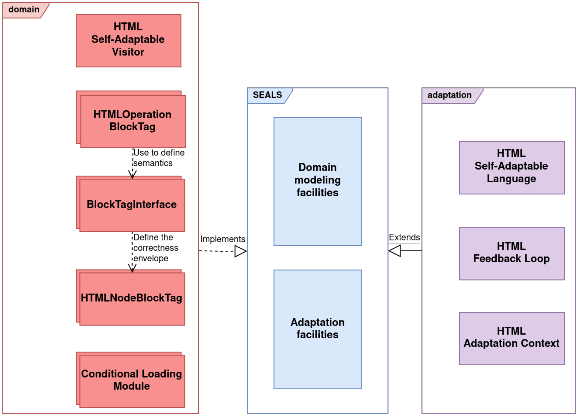
1. Define the abstract syntax
2. Create the correctness envelope



Approach overview on the HTML use case

Modeling of domain concepts

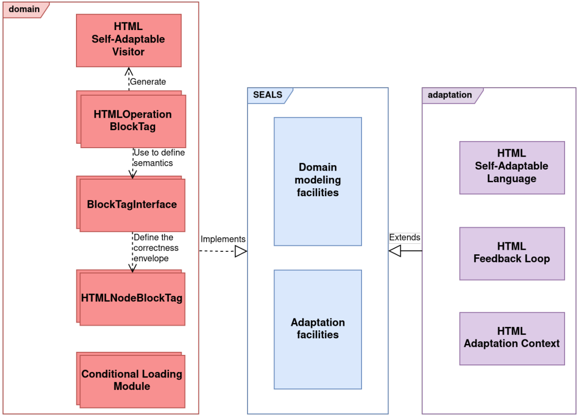
1. Define the abstract syntax
2. Create the correctness envelope
3. Implement the operations



Approach overview on the HTML use case

Modeling of domain concepts

1. Define the abstract syntax
2. Create the correctness envelope
3. Implement the operations
4. Generate the concrete visitor



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Modeling of domain concepts

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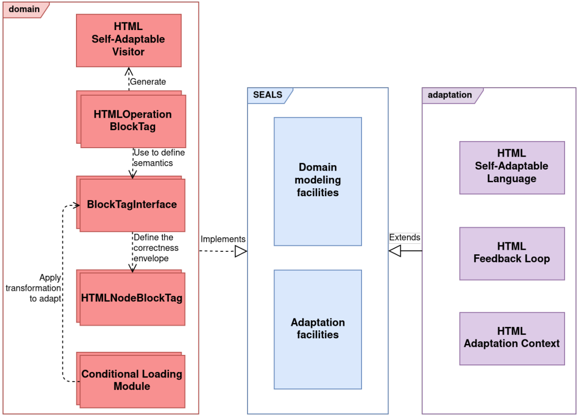
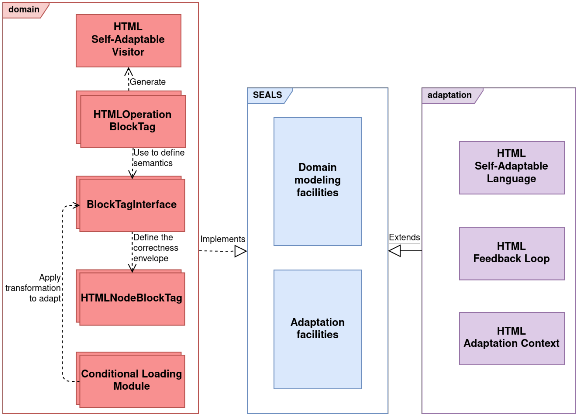
→ Develop adaptation modules



Approach overview on the HTML use case

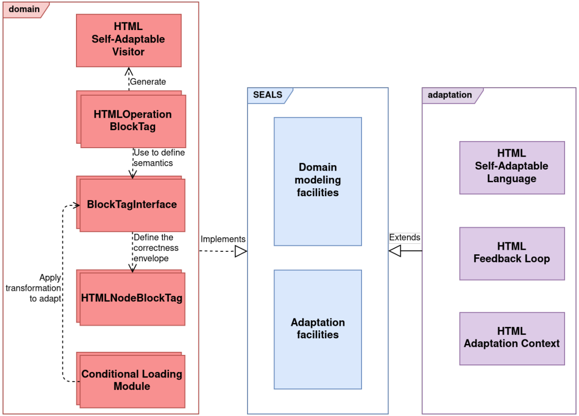
Specialize the adaptation process



Approach overview on the HTML use case

Specialize the adaptation process

1. Specialize the Adaptation Context
   - Define the KPIs
   - Define the monitored resources



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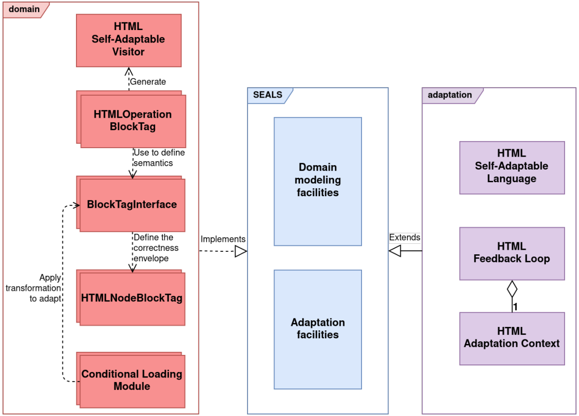
Specialize the adaptation process

1. Specialize the Adaptation Context
   - ▶ Define the KPIs
   - ▶ Define the monitored resources
2. Specialize the Feedback loop
   - ▶ Implement the **MAPE** steps
   - ▶ Define the loop trigger



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1. Specialize the Adaptation Context
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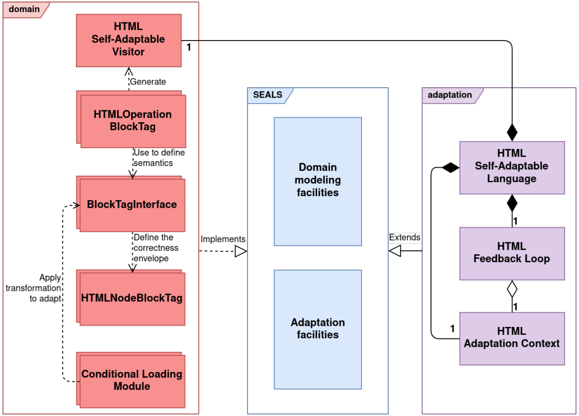
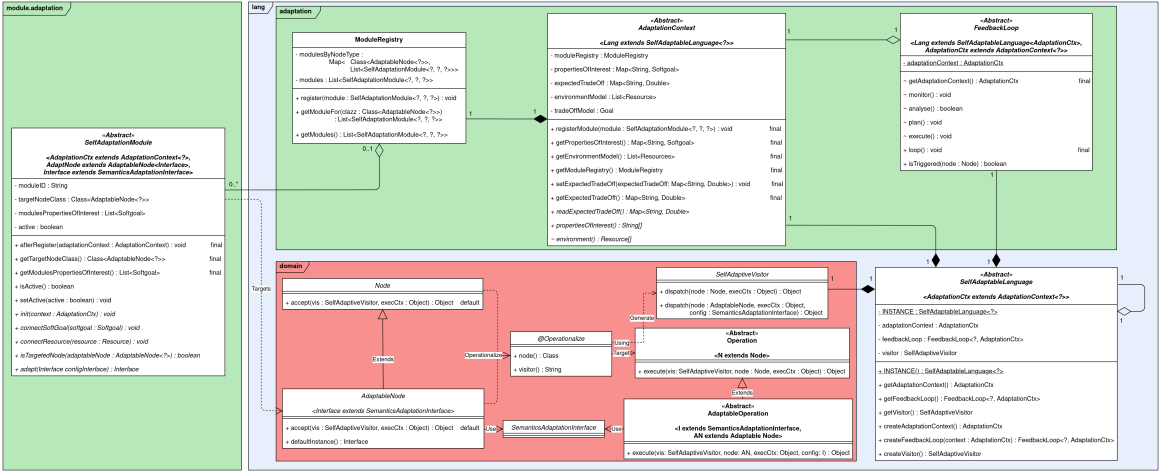
2. Specialize the Feedback loop
   - Implement the **MAPE** steps
   - Define the loop trigger
3. Connect the components



Approach overview on the HTML use case

Java Implementation



module.adaptation

«Abstract»
SelfAdaptationModule

<AdaptationCtx extends AdaptationContext<?>,
AdaptNode extends AdaptableNode<Interface>,
Interface extends SemanticsAdaptationInterface>

- moduleID : String
- targetNodeClass : Class<AdaptableNode<?>>
- modulesPropertiesOfInterest : List<Softgoal>
- active : boolean

+ afterRegister(adaptationContext : AdaptationContext) : void final
+ getTargetNodeClass() : Class<AdaptableNode<?>> final
+ getModulesPropertiesOfInterest() : List<Softgoal> final
+ isActive() : boolean
+ setActive(active : boolean) : void
+ *init(context : AdaptationCtx) : void*
+ *connectSoftGoal(softgoal : Softgoal) : void*
+ *connectResource(resource : Resource) : void*
+ *isTargetedNode(adaptableNode : AdaptableNode<?>) : boolean*
+ *adapt(Interface configInterface) : Interface*

lang

adaptation

ModuleRegistry

- modulesByNodeType :
  Map< Class<AdaptableNode<?>>,
  List<SelfAdaptationModule<?, ?, ?>>>
- modules : List<SelfAdaptationModule<?, ?, ?>>

+ register(module : SelfAdaptationModule<?, ?, ?>) : void
+ getModuleFor(clazz : Class<AdaptableNode<?>>)
  : List<SelfAdaptationModule<?, ?, ?>>
+ getModules() : List<SelfAdaptationModule<?, ?, ?>>

«Abstract»
AdaptationContext

<Lang extends SelfAdaptableLanguage<?>>

- moduleRegistry : ModuleRegistry
- propertiesOfInterest : Map<String, Softgoal>
- expectedTradeOff : Map<String, Double>
- environmentModel : List<Resource>
- tradeOffModel : Goal

+ registerModule(module : SelfAdaptationModule<?, ?, ?>) : void final
+ getPropertiesOfInterest() : Map<String, Softgoal> final
+ getEnvironmentModel() : List<Resources> final
+ getModuleRegistry() : ModuleRegistry final
+ setExpectedTradeOff(expectedTradeOff: Map<String, Double>) : void final
+ getExpectedTradeOff() : Map<String, Double> final
+ *readExpectedTradeOff() : Map<String, Double>*
+ *propertiesOfInterest() : String[]*
~ *environment() : Resource[]*

«Abstract»
FeedbackLoop

<Lang extends SelfAdaptableLanguage<AdaptationCtx>,
AdaptationCtx extends AdaptationContext<?>>

- adaptationContext : AdaptationCtx

~ getAdaptationContext() : AdaptationCtx final
~ monitor() : void
~ analyse() : boolean
~ plan() : void
~ execute() : void
+ loop() : void final
+ isTriggered(node : Node) : boolean

domain

Node

+ accept(vis : SelfAdaptiveVisitor, execCtx : Object) : Object default

AdaptableNode

<Interface extends SemanticsAdaptationInterface>

+ accept(vis : SelfAdaptiveVisitor, execCtx : Object) : Object default
+ defaultInstance() : Interface

@Operationalize

+ node() : Class
+ visitor() : String

SelfAdaptiveVisitor

+ dispatch(node : Node, execCtx : Object) : Object
+ dispatch(node : AdaptableNode, execCtx : Object,
  config : SemanticsAdaptationInterface) : Object

«Abstract»
Operation

<N extends Node>

+ execute(vis: SelfAdaptiveVisitor, node : Node, execCtx : Object) : Object

SemanticsAdaptationInterface

«Abstract»
AdaptableOperation

<I extends SemanticsAdaptationInterface,
AN extends Adaptable Node>

+ execute(vis: SelfAdaptiveVisitor, node: AN, execCtx: Object, config: I) : Object

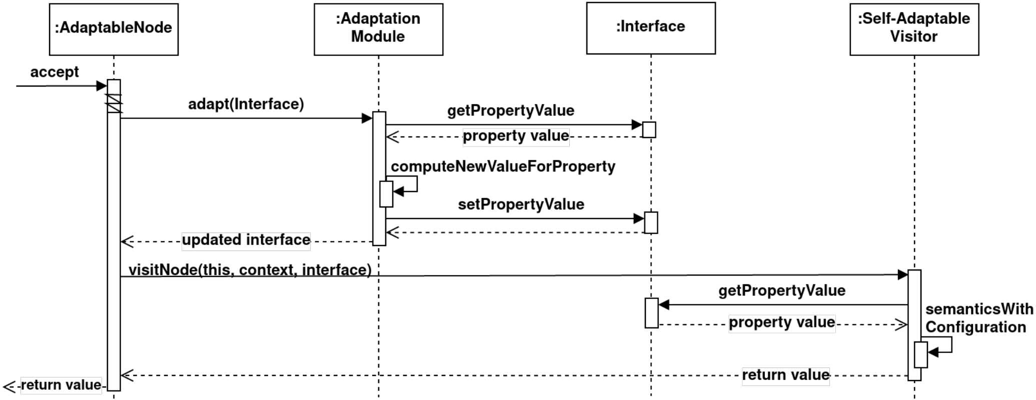
«Abstract»
SelfAdaptableLanguage

<AdaptationCtx extends AdaptationContext<?>>

- INSTANCE : SelfAdaptableLanguage<?>
- adaptationContext : AdaptationCtx
- feedbackLoop : FeedbackLoop<?, AdaptationCtx>
- visitor : SelfAdaptiveVisitor

+ INSTANCE() : SelfAdaptableLanguage<?>
+ getAdaptationContext() : AdaptationCtx
+ getFeedbackLoop() : FeedbackLoop<?, AdaptationCtx>
+ getVisitor() : SelfAdaptiveVisitor
+ createAdaptationContext() : AdaptationCtx
+ createFeedbackLoop(context : AdaptationCtx) : FeedbackLoop<?, AdaptationCtx>
+ createVisitor() : SelfAdaptiveVisitor

Correctness envelope implementation



Example of use of the correctness envelope

Abstraction

Is the set of proposed constructs relevant for a language engineer ?

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Two mandatory components :

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Two mandatory components :

- The Feedback Loop (MAPE-K [2])
  - *Adaptation Context* (**K**)
  - *Feedback Loop* (**MAPE**)

[2] IBM, “An architectural blueprint for autonomic computing,” *IBM White Paper*, vol. 31, 2006

Abstraction

Is the set of proposed constructs relevant for a language engineer ?

Two mandatory components :

- The Feedback Loop (MAPE-K [2])
  - *Adaptation Context* (**K**)
  - *Feedback Loop* (**MAPE**)
- The Operational Semantics
  - *Adaptable Operation* / *Operation*
  - Correctness envelope

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Abstraction

Is the set of proposed constructs relevant for a language engineer ?

Two mandatory components :

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  - *Adaptation Context* (**K**)
  - *Feedback Loop* (**MAPE**)
- The Operational Semantics
  - *Adaptable Operation* / *Operation*
  - Correctness envelope

→ Abstraction of their interactions ←

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Correctness envelope

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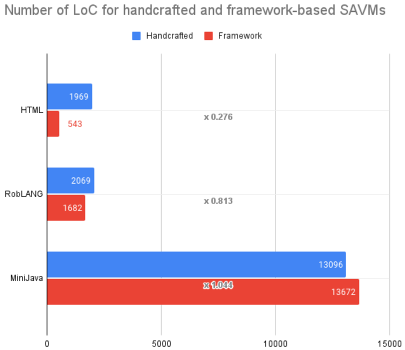
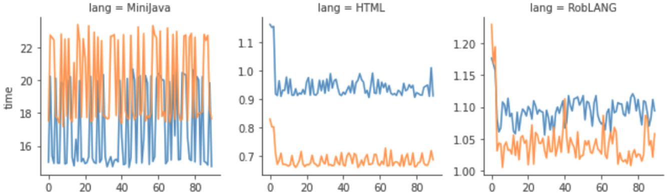
- Prevent adaptations execution as default behavior
- Allowing adaptations requires to :
  - Define subjects of adaptation
  - Implement operations on them
- Semantics changes are bounded by the set of possible instances

Performances and code size





- Operations implementation as class is heavy
- No general trend
- These results point to future work

Conclusion

The SEALS Framework . . .

- Provides abstractions to define Self-Adaptive Virtual Machines
  - Language abstract syntax and operational semantics
  - The feedback loop and associated trade-off reasoning
- Provides abstractions to define and restrain adaptations
  - Adaptations and the predictive model of their impact on the trade-off
  - Correctness envelope defining the valid semantics for a domain concept

Github repository : `https://github.com/gwendal-jouneaux/SEALS`

Perspectives

- Language tooling for better understanding by the language user.
- Managing the feature interaction between adaptations
- A principled approach to Self-Adaptable Virtual Machines
- Work on the framework performances

References

- G. Jouneaux, O. Barais, B. Combemale, and G. Mussbacher, “Towards Self-Adaptable Languages,” in *Onward! 2021*, Chicago, United States, Oct. 2021. [Online]. Available: `https://hal.inria.fr/hal-03318816`.
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