Towards Self-Adaptable Languages

<u>Gwendal Jouneaux</u>¹ Olivier Barais¹ Benoit Combemale¹ Gunter Mussbacher²

¹Univ. Rennes, Inria, IRISA – Rennes, France

²McGill University – Montreal, Canada



Onward! — October 20, 2021



Towards Self-Adaptable Languages - Jouneaux et al.

Introduction
•0

Context

Software ...



Conclusion

Context

Introduction

Software ...

Evolve in complex/changing environment (e.g, Cloud, embedded systems)



Introduction

Software ...

- Evolve in complex/changing environment (e.g, Cloud, embedded systems)
- Need dynamic adaptation to best deliver the service (e.g., Waymo¹, Netflix¹)

1 Cf. https://waymo.com, https://www.netflix.com

Introduction

Software ...

- Evolve in complex/changing environment (e.g, Cloud, embedded systems)
- Need dynamic adaptation to best deliver the service (e.g., Waymo¹, Netflix¹)

Software languages ...

1 Cf. https://waymo.com, https://www.netflix.com

Introduction

Software ...

- Evolve in complex/changing environment (e.g, Cloud, embedded systems)
- Need dynamic adaptation to best deliver the service (e.g., Waymo¹, Netflix¹)

Software languages ...

Can abstract concerns into high level constructs (e.g., memory management)

1 Cf. https://waymo.com, https://www.netflix.com

Introduction

Software ...

DiverSE

- Evolve in complex/changing environment (e.g, Cloud, embedded systems)
- Need dynamic adaptation to best deliver the service (e.g., Waymo¹, Netflix¹)

Software languages ...

Can abstract concerns into high level constructs (e.g., memory management)

Vision : abstract self-adaption into high level language constructs

¹ Cf. https://waymo.com, https://www.netflix.com

Evaluation C 00 0

Contribution overview

- $1. \ \mbox{The novel concept of Self-Adaptable Language}$
- 2. A conceptual reference framework (L-MODA)
- 3. Emerging results on the concept of Self-Adaptable Virtual Machines
- 4. A research road-map for Self-Adaptable Languages

DiverSE

Self-Adaptable Language

EvaluationConcl0000

What is a Self-Adaptable Language ?

" A software language that abstracts the design and execution of feedback loops in the design-time environment and the run-time environment "

- $1. \ \mbox{Free the language user from the implementation of}$:
 - The feedback loop
 - The trade-off analysis
- 2. Allow continuous and automatic evolution of itself

 $\begin{array}{c} \mathsf{Self}\mathsf{-}\mathsf{Adaptable} \ \mathsf{Language} \\ \circ \bullet \circ \end{array}$

Self-Adaptable Virtual Machines

Evaluation 00 Conclusion

L-MODA | Languages, Models, and Data



L-MODA Reference Framework for Self-Adaptable Languages



 $\begin{array}{c} \text{Self-Adaptable Language} \\ \circ \bullet \circ \end{array}$

Self-Adaptable Virtual Machines

Evaluation 00 Conclusion

L-MODA | Languages, Models, and Data



1) Runtime Feedback Loop

Use run-time data, model & metamodel \rightarrow adaptation of language semantics

L-MODA Reference Framework for Self-Adaptable Languages



Self-Adaptable Language ••• Self-Adaptable Virtual Machines

Evaluation 00 Conclusion

L-MODA | Languages, Models, and Data



L-MODA Reference Framework for Self-Adaptable Languages

1) Runtime Feedback Loop

Use run-time data, model & metamodel \rightarrow adaptation of language semantics

2) Design Feedback Loop

Use design-time data, models & metamodel \rightarrow adaptation of syntax, pragmatics & semantics



 $\begin{array}{c} \mathsf{Self}\mathsf{-}\mathsf{Adaptable} \ \mathsf{Language} \\ \circ \bullet \end{array}$

Self-Adaptable Virtual Machines

Evaluation 00 Conclusion

L-MODA | Stakeholders



L-MODA Reference Framework for Self-Adaptable Languages



 $\begin{array}{c} \mathsf{Self}\mathsf{-}\mathsf{Adaptable} \ \mathsf{Language} \\ \circ \circ \bullet \end{array}$

Self-Adaptable Virtual Machines

Evaluation 00 Conclusion

L-MODA | Stakeholders

Various uses of the feedback loops ...



L-MODA Reference Framework for Self-Adaptable Languages



 $\begin{array}{c} \mathsf{Self}\mathsf{-}\mathsf{Adaptable} \ \mathsf{Language} \\ \circ \circ \bullet \end{array}$

Self-Adaptable Virtual Machines

uation Co

L-MODA | Stakeholders

Various uses of the feedback loops ...



Examples for the Runtime Feedback Loop :

L-MODA Reference Framework for Self-Adaptable Languages



Towards Self-Adaptable Languages - Jouneaux et al.

Self-Adaptable Language $\circ \circ \bullet$

Self-Adaptable Virtual Machines

uation Con

L-MODA | Stakeholders

Various uses of the feedback loops ...

Language Language Specifications Engineer (Metamodels) Language Data System 1 Language Specifications **Running in IDE** User (Models) Running Data Software End User Language Data Socio-Technical Runtime Modeling System

L-MODA Reference Framework for Self-Adaptable Languages



Towards Self-Adaptable Languages - Jouneaux et al.

 $\mathsf{Examples}$ for the Runtime Feedback Loop :





Self-Adaptable Language

Self-Adaptable Virtual Machines

uation Con

L-MODA | Stakeholders

Various uses of the feedback loops ...

Language Language Specifications Engineer (Metamodels) Language Data System 1 Language Specifications User **Running in IDE** (Models) Running Data Software End User Language Data Socio-Technical Runtime Modeling System

L-MODA Reference Framework for Self-Adaptable Languages



Towards Self-Adaptable Languages - Jouneaux et al.

Language engineer in complete control Tailor the language to a particular trade-off

K Language user custom adaptations Configure the adaptations for a system

Examples for the Runtime Feedback Loop :

Self-Adaptable Language

Self-Adaptable Virtual Machines

luation Con

L-MODA | Stakeholders

Various uses of the feedback loops ...

Language Language Specifications Engineer (Metamodels) Language Data System 1 Language Specifications User **Running in IDE** (Models) Running Data Software End User Language Data Socio-Technical Runtime Modeling System

L-MODA Reference Framework for Self-Adaptable Languages



X Language user custom adaptations Configure the adaptations for a system

Examples for the Runtime Feedback Loop :

End-user preferences Indicate preference for trade-offs



Self-Adaptable Language

Self-Adaptable Virtual Machines

Evaluation 00 Conclusion

Experimentation

The case of Self-Adaptable Virtual Machines



Evaluation 00 Conclusion

What are Self-Adaptable Virtual Machines

- A specific case of Self-Adaptable Languages
- Runtime Feedback loop in language operational semantics
- ▶ In our experiment : Pluggable architecture with delegation of responsibilities



DiverSE

Self-Adaptable	Virtual	Machines	
0000			

Evaluation 00 Conclusion

Motivating Examples



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

Evaluation 00 Conclusion

Adaptations



Evaluation 00 Conclusion

Adaptations (MiniJava)

Applied Approximate Loop Unrolling [1] on image processing algorithm (Sobel)



Standard output



Approximated output

[1] M. Rodriguez-Cancio, B. Combemale, and B. Baudry, "Approximate loop unrolling," in *Proceedings of the* 16th ACM International Conference on Computing Frontiers, ACM, 2019



Towards Self-Adaptable Languages - Jouneaux et al.

Evaluation 00 Conclusion

Adaptations (MiniJava)

Applied Approximate Loop Unrolling [1] on image processing algorithm (Sobel)



Standard output



Approximated output

[1] M. Rodriguez-Cancio, B. Combemale, and B. Baudry, "Approximate loop unrolling," in *Proceedings of the* 16th ACM International Conference on Computing Frontiers, ACM, 2019



Towards Self-Adaptable Languages - Jouneaux et al.

Self-Adaptable Virtual Machines

Evaluation 00 Conclusion

Adaptations (RobLANG)

Applied a motor speed reduction on basic actions

Rational :
$$P_i = P_{max}(\frac{Speed_i}{Speed_{max}})^3$$
 [2]

Three programs studied :

- Move forward/backward
- Turn left/right
- Combination of moves and turns (square patterns)

[2] A. Al-Mofleh, S. Taib, W. Salah, et al., "Importance of energy efficiency: From the perspective of electrical equipments," in *Proceedings of the 2nd International Conference on Science and Technology (ICSTIE)*, 2008



Self-Adaptable Language

Self-Adaptable Virtual Machines

EvaluationConcl0000

Adaptations (HTML)

amazon States Al + compilers principles, techni	iques, and tools	۹. 🗖	Holo, Sign in Accessed & Lists - & Orders	
₩ Today's Deals Castorner Service Registry GPt Cards	Sell		Amazor's response to COVID-19	
1-16 of 315 results for "compilers principles, to	echniques, and tools"		Sort by: Restand W	Conditional loading of secondary
Heyartanif Barti Barti Campato Internet Campato Campato Internet Campato Campato Internet Campato Internet	Consider: Propose Term Construction Constr	inligues, and Tools		 Conditional loading of resourt Perforation of HTML lists Image degradation
ingratish Programmers ingratish Programmers ingr	Completes Completes Reserved R	niques, & Tools e.e. Jon 1, 2012	Þ	Applied on the top 100 websites
Computer ther Basks Importance & Starton Importance & Starton Importance & Proper Users Importance Basks Foresat Paperback	Compilers: Principles, Ter () Attenty of the start, etc. Start and the start	niques, and Tools 0 07 1, 1985		ightarrow 45 still deliver the content

Standard website



Towards Self-Adaptable Languages - Jouneaux et al.

elf-Adaptable Language

Self-Adaptable Virtual Machines

Evaluation 00

Adaptations (HTML)



1-16 of 70 results for"compilers principles, techniques, and tools" Sort by: [induct _____]Sort by:Featured



Compilers: Principles, Techniques, and Tools

by Alfred Aho, Monica Lam, et al. | Aug 31, 2006 4.2 out of 5 stars318 Bardcover 579.36579.36to rent Cely 16 lott in stock - order soon.

eTexthock \$39.99\$39.99to rent \$74.99to buy Available instantly





- Conditional loading of resources
- Perforation of HTML lists
- Image degradation

Applied on the top 100 websites \rightarrow 45 still deliver the content

Adapted website



Towards Self-Adaptable Languages - Jouneaux et al.

Evaluation •0 Conclusion

Relevance of proposed adaptation

TL;DR : Good results but ...

Performance overhead

- Deal with the diversity of programs oblivious of the adaptations performed
- Lack of control on the adaptations

elf-Adaptable Language

Self-Adaptable Virtual Machines

Evaluation •0

Relevance of proposed adaptation (MiniJava)



Correct adaptation behavior

 Results emphasize the need for a more efficient implementation of the adaptation system

Sobel filter mean execution time depending on the CPU usage



elf-Adaptable Language

Self-Adaptable Virtual Machines

Evaluation Co • 0 0

Relevance of proposed adaptation (RobLANG)

Prog	Relaxation of the time constraint (in %)						
Frog.	0% *	25%	50%	75%			
Turn	288	524 (182%)	1164 (404%)	3018 (1048%)			
Move 87		154 (177%)	330 (379%)	860 (989%)			
Square 74 14		142 (192%)	294 (397%)	794 (1073%)			
Mean	1036.06%						
(*) We use the original interpreter as baseline.							

Number of actions performed by robot (and relative enhancements compared to the baseline) depending on the program and the percentage of time constraint relaxation.



elf-Adaptable Language

Self-Adaptable Virtual Machines

EvaluationConclu•000

Relevance of proposed adaptation (HTML)



Websites consumption when browsing normally versus using the HTML SAVM

Distribution of energy reduction ratios



150

DiverSE

elf-Adaptable Language

Self-Adaptable Virtual Machines

Evaluation 0

Language-level vs System-level abstraction

Attempt to implement as library of the language

VMs	Feedback loop	Trade-off reasoning	Feedback loop calls	Interaction with the domain
MiniJava	=	=	+	+
RobLang	=	+ +	+	-
HTML (JS)	=	=	=	-

Comparison of implementation simplicity (+ in favor of language-level)

Evaluation 00 Conclusion

Conclusion

- The concept of Self-Adaptable Language and its conceptual framework
- Proof-of-concept implementation of Self-Adaptable Virtual Machines
- Promising results for adaptations of language operational semantics



Conclusion

Future work

...

Support of the Runtime Feedback Loop

- Feedback loop configuration
- A reference framework for common implementation [3]

Support of the Design Feedback Loop

- Model the development context
- Detect evolution opportunities
- Navigate in evolution of programs

[3] G. Jouneaux, O. Barais, B. Combemale, *et al.*, "SEALS: A framework for building Self-Adaptive Virtual Machines," in *Proceedings of the 14th ACM SIGPLAN International Conference on Software Language Engineering (SLE '21)*, Chicago, United States, Oct. 2021. DOI: 10.1145/3486608.3486912

...



Future work

...

Support of the Runtime Feedback Loop

- Feedback loop configuration
- A reference framework for common implementation [3]

Support of the Design Feedback Loop

Conclusion

- Model the development context
- Detect evolution opportunities
- Navigate in evolution of programs

For more details take a look at our research roadmap

...

[3] G. Jouneaux, O. Barais, B. Combemale, *et al.*, "SEALS: A framework for building Self-Adaptive Virtual Machines," in *Proceedings of the 14th ACM SIGPLAN International Conference on Software Language Engineering (SLE '21)*, Chicago, United States, Oct. 2021. DOI: 10.1145/3486608.3486912



References

- M. Rodriguez-Cancio, B. Combemale, and B. Baudry, "Approximate loop unrolling," in *Proceedings of the 16th ACM International Conference on Computing Frontiers*, ACM, 2019.
- A. Al-Mofleh, S. Taib, W. Salah, and M. Azizan, "Importance of energy efficiency: From the perspective of electrical equipments," in *Proceedings of the 2nd International Conference on Science and Technology (ICSTIE)*, 2008.
- G. Jouneaux, O. Barais, B. Combemale, and G. Mussbacher, "SEALS: A framework for building Self-Adaptive Virtual Machines," in *Proceedings of the 14th ACM SIGPLAN International Conference on Software Language Engineering (SLE '21)*, Chicago, United States, Oct. 2021. DOI: 10.1145/3486608.3486912.

