Incremental Model Synchronization for Efficient Run-time Monitoring

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Motivation

- Self-adaptive software [Cheng et al., 2008] and autonomic computing [Kephart and Chess, 2003]
- Parameter & architectural adaptations [McKinley et al., 2004]

→ Monitoring parameters & architecture: **model of a running system**

- Capabilities: self-configuration, self-healing, self-optimization, self-protection [Lin et al., 2005]

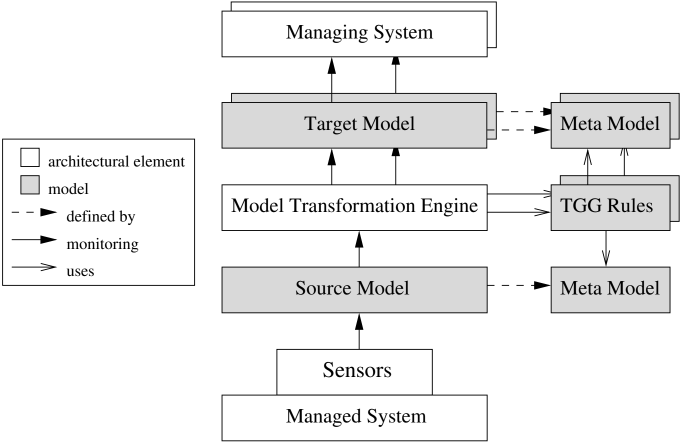
→ Monitoring with respect to different aspects: **different models**

- Runtime

→ Efficient solution: **incremental techniques**

Incremental Model Synchronization for Efficient Run-time Monitoring

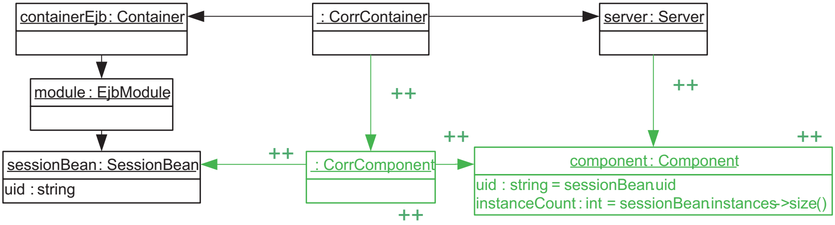
Generic Architecture



- Model Transformation Engine based on **Triple Graph Grammars (TGG)** [Giese and Hildebrandt, 2008, Giese and Wagner, 2009]

Incremental Model Synchronization

- Triple graph grammars: source, correspondence, and target model
- Example TGG Rule:

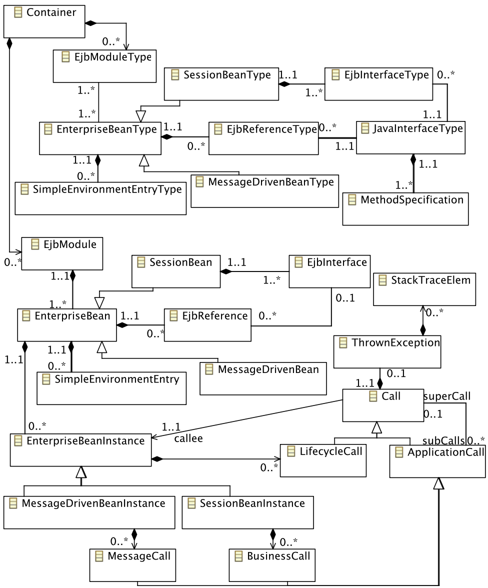


- Incremental synchronization: event-driven, local sync. strategies
- Automatic generation of operational rules from TGG rules

Implementation

- Engine and models are based on the **Eclipse Modeling Framework** (EMF) (decoupled from the Eclipse workbench)
- Models conform to EMF meta models
- Managed systems are **Enterprise Java Beans 3.0** (EJB) applications
- EJB infrastructure **mKernel** provides sensors as an API [Bruhn et al., 2008] for the **Glassfish** application server

Source Meta Model for EJB

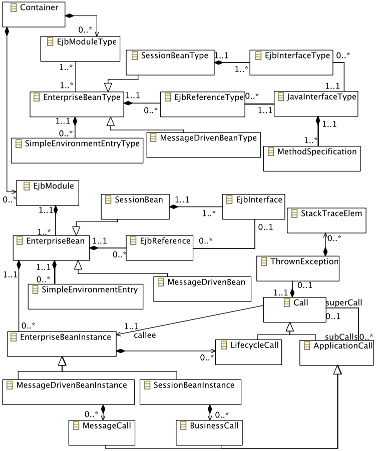


Complexity:

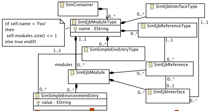
- Types of components
- Deployed components and their configurations
- Concrete instances and interactions

→ **Abstraction for different aspects**

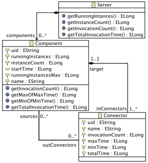
Multiple Run-time Models



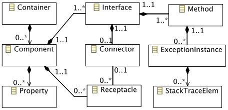
Source Meta Model



Architectural constraints for self-configuration



Performance for self-optimization



Failures for self-healing

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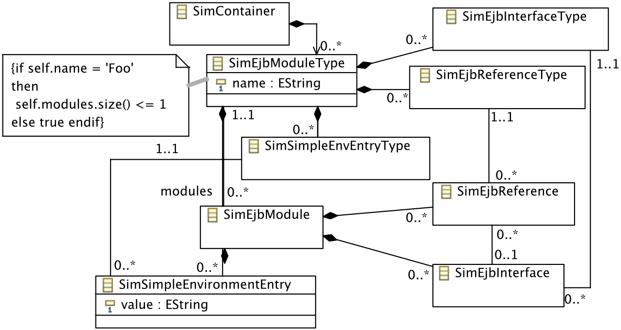
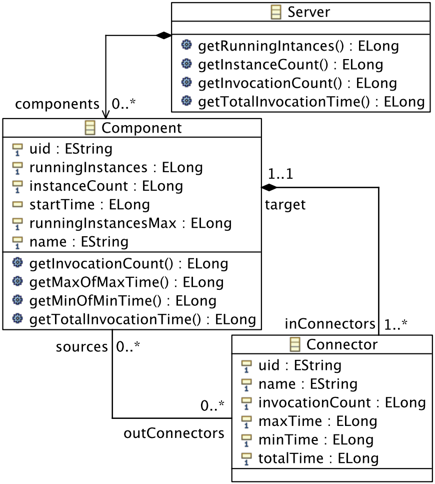
Architectural Target Meta Model



Self-Configuration

- Simplified run-time architectures of EJB-based applications
- Checking architectural constraints using OCL

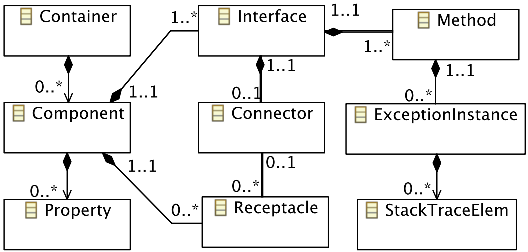
Performance Target Meta Model



Self-Optimization

- Architectural information enriched with performance data

Failure Target Meta Model



Self-Healing

- Architectural information enriched with occurred failures

Related Work

- Maintaining run-time models non-inrementally [Hein et al., 2007]
- Single view provided by run-time models [Dubus and Merle, 2006, Morin et al., 2008]
- No advanced model-driven techniques, like model transformation [Dubus and Merle, 2006, Hein et al., 2007, Morin et al., 2008]
- Model transformation at run-time [Song et al., 2008]
  - File-based synchronizations (*MediniQVT*)
  - Source model does not seem to be maintained at run-time and therefore non-incremental synchronizations seem to be involved

Conclusion & Future Work

Conclusion

- Multiple run-time models for monitoring
- Incremental model synchronization at run-time
- Efficient solution (for evaluation see paper)

Future Work

- Incremental model synchronization for adaptations
- Architectural adaptations

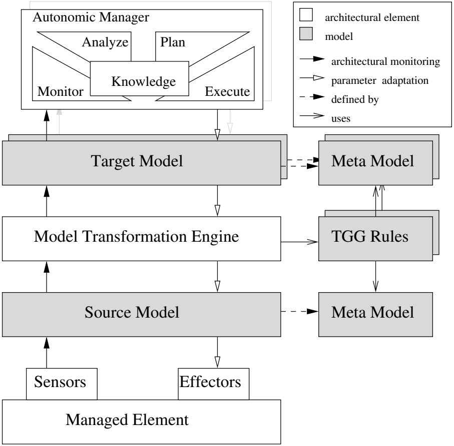


Figure: Monitoring and Adaptations [Vogel et al., 2009]

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Backup

Incremental Model Synchronization

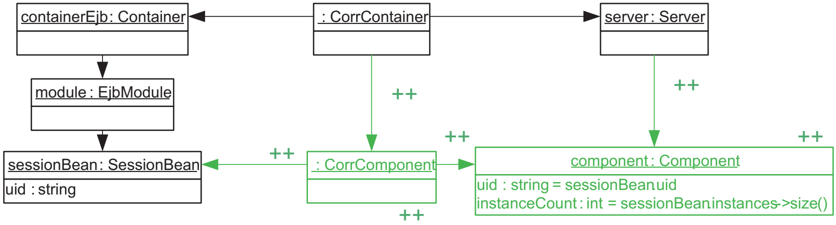
- Notification mechanism to efficiently detect modifications of source model elements
- Notification contains the relevant correspondence model element
- Correspondence model to efficiently navigate between source and target model
- Check consistency of source and target model elements
- Modification of the target model to reestablish consistency
    - Attribute values, links, nodes
- Queueing of notifications and on-demand synchronization

→ **Incremental synchronization of a source and a target model**

TGG Rules for Performance Meta Model

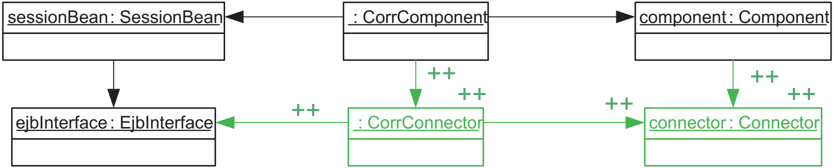
1st rule (axiom):

2nd rule:

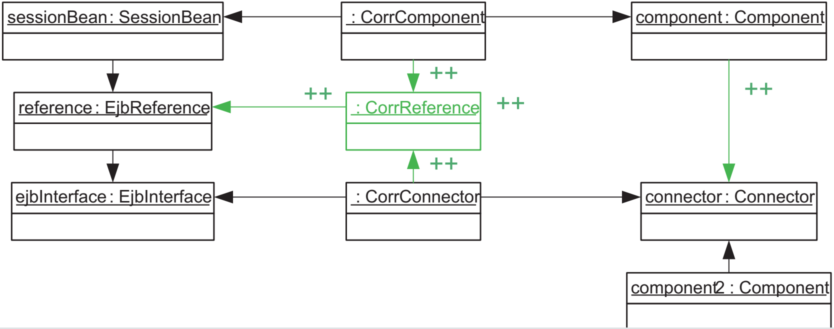


TGG Rules for Performance Meta Model (2)

3rd rule:



4th rule:



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Evaluation

Comparing three approaches regarding development costs and performance:

- **Model-Driven Approach**
- **Non-Incremental Adapter (NIA)**
- **Incremental Adapter (IA)**

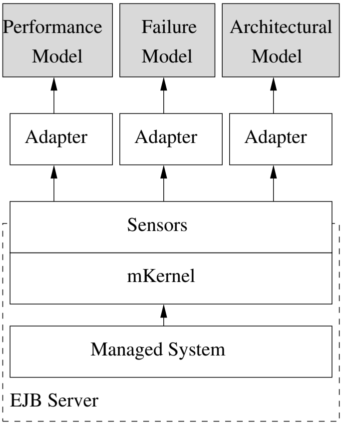

Figure: NIA/IA

Development Costs

Target Model	Model-Driven Approach Rules	Nodes/Rules	LOC	NIA LOC
Simpl. Architectural Model	9	7,44	15259	357
Performance Model	4	6,25	5979	253
Failure Model	7	7,14	12133	292
Sum	20		33371	902

- **Model-Driven Approach**: 2685 LOC for the EMF Adapter
- **Incremental Adapter**: 30k LOC?
- Declarative vs. imperative approaches
- **Non-Incremental Adapter (NIA)**: 20 TGG rules $\approx$ 902 LOC

Performance

Size	NIA		Model-Driven Approach						
	S	*B*	n=0	n=1	n=2	n=3	n=4	n=5	*B*
5	8037	20967	0	163	361	523	749	891	10733
10	9663	43054	0	152	272	457	585	790	23270
15	10811	72984	0	157	308	472	643	848	36488
20	12257	105671	0	170	325	481	623	820	55491
25	15311	142778	0	178	339	523	708	850	72531

[ms]

- **Size**: number of deployed beans
- Monitoring structural (**S**) and behavioral (**B**) aspects
- Pull-oriented (**S** & **B**) and push-oriented (**S**) monitoring
- **n**: number of events reflecting structural changes
- **Model-Driven Approach:** Depending on n, 3.7% to 7.2% of the average times for structural monitoring are used for model synchronization, the rest for event processing.

Performance for Architectural Monitoring

Size	Model-Driven Approach					
	n=0	n=1	n=2	n=3	n=4	n=5
5	0	163	361	523	749	891
10	0	152	272	457	585	790
15	0	157	308	472	643	848
20	0	170	325	481	623	820
25	0	178	339	523	708	850
Event processing	0%	92.8%	94.1%	95.6%	95.2%	96.3%
Synchronization	0%	7.2%	5.9%	4.4%	4.8%	3.7%

[ms]

- **Size**: number of deployed beans
- Architectural monitoring through event-driven sensors
- Processing **n** events and invoking **once** the transformation engine

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