Technische Universität Braunschweig

Controlling Concurrent Change

IDA INSTITUTE OF COMPUTER AND NETWORK ENGINEERING

An extensible autonomous reconfiguration framework for complex component-based embedded systems (ICAC’15)

Johannes Schlatow, Mischa Möstl, Rolf Ernst

{schlatow|moestl|ernst}@ida.ing.tu-bs.de

Motivation

Scenario:

- Single platform with **multiple owners**
- **Extra-functional** requirements (safety, security, timing, …)

  e.g. **automotive** applications: ISO26262 → freedom from interference

Goals:

- **Incremental** changes (updates, extensions, customisation)
- Long-term **evolution**

Lab-centric integration → autonomous in-field "update"

Problem Statement

Incremental integration

Given: current system configuration, set of components to be deployed

Wanted: new and valid system configuration

- A **valid configuration** must fulfil all requirements.
- (Extra-)functional requirements are specified by **component contracts**.
- Support additional **optimisation objectives** (e.g. minimum changes).
- **Reuse** established models and analyses where possible.

→ **Find valid system reconfigurations for incremental change requests.**

→ **Integrate established formal analyses for (efficient) verification.**

Related Work

Related Work

- *[Dearle et al. 2004]:* constraint-based deployment of distributed applications (mapping and interconnect)
- *[Jenson et al. 2010]:* SAT encoding for component-level dependencies
- *[Panunzio, Vardanega 2014], [Gleirscher et al. 2007]:* lab-based design processes covering multiple views
- *[Sojka, Hanzalek 2009], [Stein et al. 2011]:* single-view contract-based self-adaptation/admission control

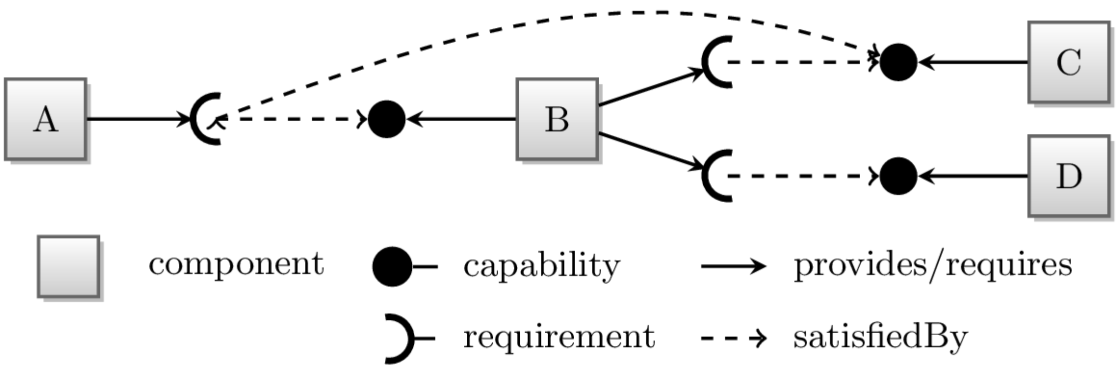
Our Contributions

1. Boolean satisfiability (SAT) approach for service-level functional dependencies in component-based systems.
2. Extensible framework for formal (contract-based) admission control of incremental changes w.r.t. multiple design views.

Component Model

Targeted run-time environments (e.g. Genode OS Framework):

- Component-based
- Service-oriented interfaces
- Explicit connections → principle of least privilege



(+ optional requirements & cardinality constraints)

C : set of components
R : set of requirements
P : set of capabilities

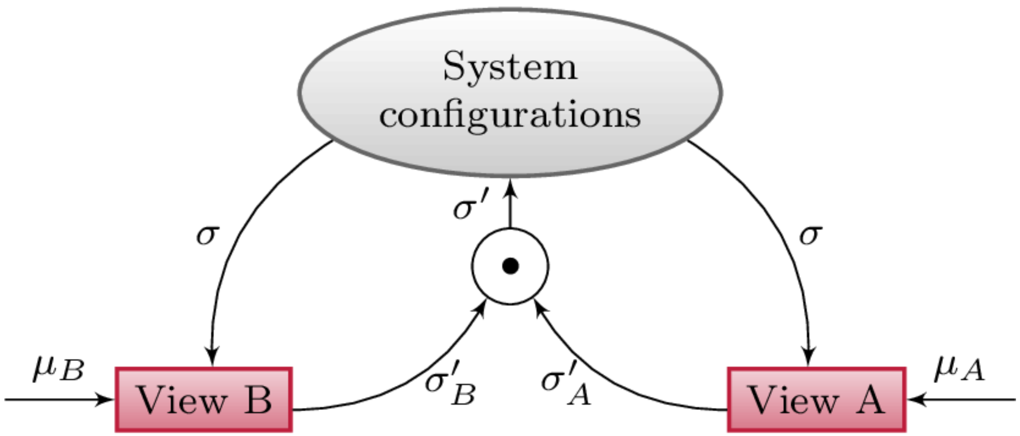
Relations:
satisfiedBy $\subseteq R \times P$
provides $\subseteq C \times P$
etc…

→ extracted from component contracts

Framework Architecture – Multi-Change Controller

Multi-Change Controller

- Implements contract-based **admission control** / **contract negotiation** (multiple applications, multiple aspects)
- Separates (extra-)functional aspects (→ **design views**)
- Central **constraint solver**
- Translates **model-specific constraints** (μ) into configuration constraints (σ)



Framework Architecture – Multi-Change Controller (cont.)

Constraint classification:

1) Necessary and sufficient: optimal, possibly extensive or not even possible
2) Only sufficient: over restrictive → avoid
3) Only necessary: under restrictive → requires sanity check
4) Separation constraints: incrementally separate unsound solutions

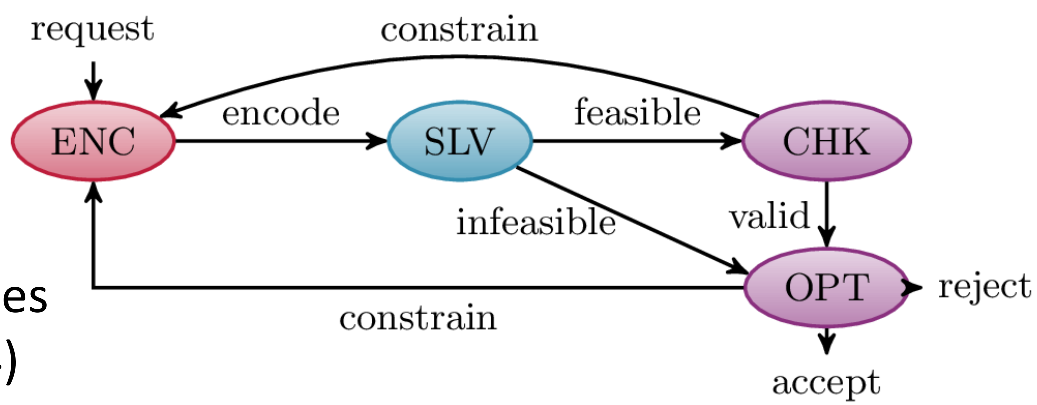
Iterative approach:

ENC: constraint encoding 1)-3)

SLV: central constraint solver

CHK: view-specific analysis engines
→ sanity check + constraints (4)

OPT: optional optimisation engines
→ design-space exploration



Component View

- Solves (service-level) **functional dependencies** between components.
- Finds functionally valid component compositions.
- Provides a **basis for** most **extra-functional views** (e.g. timing).

Requirements

1) A component must be instantiated if explicitly queried.
2) <u>A component must be instantiated if one of its capabilities is used.</u>
3) …

Encoded as Boolean constraints (SAT), e.g. 2):

$$\forall (j,k) \in S: \neg s_{jk} \vee p_k$$
$$\forall (i,k) \in P: \neg p_k \vee c_i$$

P : set of capabilities
S : set of connections
$c_i = True \Leftrightarrow$ component i must be instantiated
$p_k = True \Leftrightarrow$ capability k must be provided
$s_{jk} = True \Leftrightarrow r_j$ is connected to p_k

Conclusion and Future Work

Conclusion

- Autonomous reconfiguration of component-based systems
- Admission control of in-field updates
- Constraint satisfaction with multiple design views
- SAT approach for service-level functional dependencies

Future Work

- Add views for timing, mapping, functional correctness, safety
- Performance evaluation on realistic, more complex use-cases

Thank you for your attention! Questions?

References

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[Stein et al. 2011]: S. Stein, M. Neukirchner, and R. Ernst
"Admission control and self-configuration in the EPOC framework," *in Intl. Conf. on Embedded Computer Systems: Architectures, Modeling, and Simulation (SAMOS XI)*, Jul. 2011.

Backup Slides

Component View – Requirements

Requirements

1) A component must be instantiated if explicitly queried.
2) All requirements of an instantiated component must be connected to a capability that satisfies the requirement.
3) All invoked requirements of an instantiated component must be connected to a capability that satisfies the requirement if and only if the invoking capability is connected.
4) A component must be instantiated if one of its capabilities is used.
5) A component should not be present if neither explicitly queried nor providing a required capability.
6) A capability p can be connected to at most $\nu(p)$ requirements.
7) Already deployed components and their connections shall not be modified during reconfiguration.

➔ **SAT (boolean satisfiability) encoding**

Component View – SAT encoding

Variables

$\forall i \in C: q_i = True \Leftrightarrow c_i$ was queried

$\forall i \in C: c_i = True \Leftrightarrow c_i$ must be instantiated

$\forall j \in R: r_j = True \Leftrightarrow r_j$ must be satisfied

$\forall k \in P: p_k = True \Leftrightarrow p_k$ must be provided

$\forall (j,k) \in S: s_{jk} = True \Leftrightarrow r_j$ is connected to p_k

C : set of components
R : set of requirements
P : set of capabilities
S : set of connections

Constraints (e.g.):

$\forall (j,k) \in S: \neg s_{jk} \vee p_k$
$\forall (i,k) \in P: \neg p_k \vee c_i$

Requirement 2:
Component is instantiated if one of its capabilities is used.