Architectural Style as an Independent Variable

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Background: Architectural style

Architectural style defines a family of systems in terms of a pattern of structural organization. A vocabulary of components and connectors, with constraints on how they can be combined.

Garlan & Shaw, 1994
Research Question

- Important outcomes depend on architectural style choices
- Lack a scientific account of choices in this dimension
  - Selection of architectural styles driven by informal analysis
  - Application of architectural style choices is a manual activity
  - Once “wired in,” architectural changes are very hard to make
- Can we develop a scientific account of architectural style as an independent variable in design, to enable the automated application of architectural style choices?
Architectural style as a separable choice

Application description

Choice of architectural style

MAP

Architecture & Properties
Example, Parnas 1972

Keyword in Context
Procedural or Information Hiding Modularity

MAP

Architecture, Ease of Change & Understanding, Parallelism in Development
Example, Taylor 2009

Lunar Lander

Wide range of architectural styles

MAP

Range of Architectures & Properties
What We Noticed and What We’re Doing

- Architectural mappings have not previously been identified as an important subject of study
- Practiced informally, intuitively, implicitly
- Our work shows the feasibility and potential value of formalizing and automating architectural mappings
Basic Idea

- Application Description $\times$ Architectural Style $\rightarrow$ Architectures

- Use published Alloy formalizations of architectural style

- Develop approach to characterizing applications in an architectural-style-neutral form, again using Alloy

- Define mapping predicates taking this combination of specifications to a space of conforming architectural descriptions
Benefits

- Pinpoint an important subject for future study

- Spread architectural abilities through automation
  - Both synthesis of architectural descriptions
  - And new forms of analysis
  - E.g., impact analysis based on partial derivatives of architectural descriptions with respect to incremental changes in application descriptions or in architectural style choices and definitions

- Improved support for reasoning about system properties
Contribution

- Demonstrated feasibility of formally treating *architectural style* as an *independent variable*

- Small-scale studies of range of application descriptions and architectural styles

- Including aspect-oriented architectures
High-Level View
Lunar-Lander Case Study

Implicit Invocation

Lunar Landing control System

High-Level View
Aspect-oriented Application Description

Pipe-and-Filter

Parnas’s KWIC
Enhanced with a logging concern
Mapping Process

Process Engine

Arch. Style

Arch. Style

App. Style

App. Desc : App. Style

Mapping Predicates (Alloy)

Set of Satisfying Solutions (Alloy)

Alloy Analyzer

A2A Transformer (Java Application)

Set of Architecture Descriptions (ADL)

ACME, AADL, UML, ...
Evaluation

- Tested the idea by
  - Exhibiting maps for
    - Several application and architectural styles
  - Check consistency with
    - Informally and manually produced results in the literature

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Result of the experimental testing of our approach
Case Study
Lunar-Lander

- Mapping *Lunar-Lander* application to architectural descriptions in the *implicit-invocation* style
module LunarLander_SCC

open SCC

... 

one sig Altimeter, FuelLevel, Gyro, EngineControlSwitch extends Sensor{}
one sig DescentEngController, Display, AttitudeControlThruster extends Actuator{}

one sig FlightControl extends Controller{}
sensors = Altimeter+ FuelLevel+ Gyro+ EngineControlSwitch
actuators = DescentEngController+ Display+ AttitudeControlThruster
controller派出dispatch state = periodic
frequency state = fast
program = controller_code
}
Map in Alloy
(Sense-Compute-Control, Implicit-Invocation)

all n: needHandle | one o: IIObject | o.handle = n
all a: Actuator | one port: Port| (port in (a.~handle.ports & Procedure) ) || (port in (a.~handle.ports & SubscribeEvent)
all s: Sensor | one port: Port| (port in (s.~handle.ports & Procedure) ) || (port in (s.~handle.ports & PublishEvent) )

# (Controller.~handle.ports & SubscribeEvent) = # (Sensor.~handle.ports & PublishEvent)
(#SubscribeEvent >0) => # (Controller.~handle.ports & PublishEvent) = 1
(#Procedure >0) => # (Controller.~handle.ports & Call) = 1
all port:Procedure| one conector: procedureCall| port[attachments].ran = conector.roles & Provide

Controller.~handle.call[attachments].ran.connector = //procedureCall
    Actuator.~handle.procedure[attachments].ran.connector +
    Sensor.~handle.procedure[attachments].ran.connector

(Controller.~handle.ports & PublishEvent)[attachments].ran.~roles =  // EventBus
(Actuator.~handle.ports & SubscribeEvent)[attachments].ran.~roles
(Controller.~handle.ports & SubscribeEvent)[attachments].ran.~roles =
(Sensor.~handle.ports & PublishEvent)[attachments].ran.~roles
...

Part of the mapping predicate represented in Alloy
Internal Models (Alloy Analyzer)

Satisfying solutions to the mapping’s constraints
Result of Mapping (in ACME)

Three computed instances of the mapping of SCC of Lunar Lander into the implicit invocation style in Acme
Related Work

- Formalization of architectural styles
  - We build on this work

- Model-based software development
  - Application platform as independent variable

- Architectural transformation
  - Horizontal vs. Vertical
Future Work

- Develop idea of application description styles
- Extend mappings to include semantics
- More complex architectural styles
- Automated design space search
- Question: Where do property specifications go?
Conclusion

- First steps toward a theory and application of *architectural maps*
- Validation by demonstration using Alloy, for a range of architectural and application styles
- Open questions about potential for utility in an industrial setting
Thank You