The Build-Time Software Architecture View

University of Waterloo

Qiang Tu

Michael Godfrey

Software Architecture Group (SWAG)

University of Waterloo

Overview

- Software architecture and the need for multiple views
- The build-time software architecture view
- Examples: GCC, Perl, JNI
- The "code robot" architectural style
- Representing build-time views in UML
- Conclusions

Software architecture

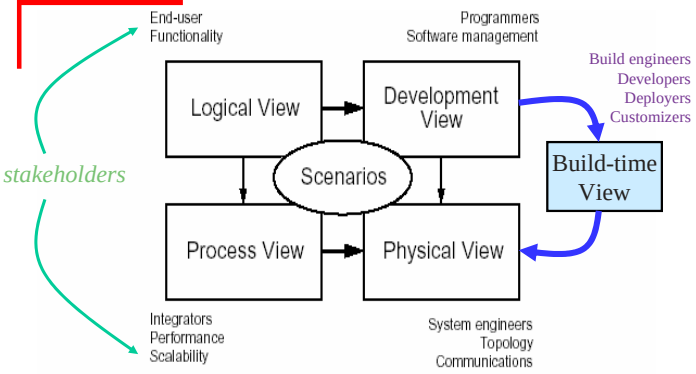
- Consists of descriptions of:
  - components, connectors, rationale/constraints, …
- Shows *high-level structure*
  - Composition and decomposition, horizontal layers and vertical slices
- Reflects *major design decisions*
  - Rationale for why one approach taken, what impact it has
- Promotes *shared mental model* among developers and other stakeholders
  - Shows how functional and non-functional requirements are met

The need for multiple views

- Stakeholders have different experiences of what the system "looks like"
  - One size does not fit all.
  - "Separation of concerns"
- Kruchten's "4+1" model:
  - Logical, development, process, physical "+" scenarios
  - Each view has different elements, different meaning for connectors, *etc.*

    [Hofmeister *et al.* proposed similar taxonomy of four views]

The (4+1)++ model



Why the build-time view?

- Many systems do not have very interesting build-time properties …
  - Straightforward, mostly static `Makefile`-like approach is good enough.
- … but some systems do!
  - They exhibit interesting *structural* and *behavioural* properties that are apparent only at *system build time*.
  - These properties are not well modelled by existing software architecture taxonomies.

Why the build-time view (BTV)?

- Want to document interesting build processes to aid program comprehension
- Targeted at different stakeholders: anyone affected by the build process
  - System "build engineers"
  - Software developers
  - End-users who need to build or customize the application
- Separation of concerns
  - Configuration/build management
- Of particular interest to open source projects

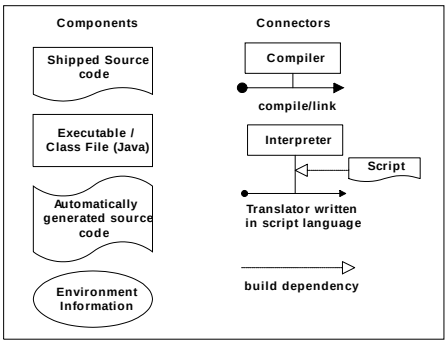
Interesting build-time activities

- Automatic "source" code generation
  - Build-time vs. development-time
    e.g., GCC *vs.* JDK
  - Targeted at a large range of CPU/OS platforms
    - Implementation (algorithms) are highly platform dependent.
    - Conditional compilation is not viable.
      - Too complicated or just inelegant

Interesting build-time activities

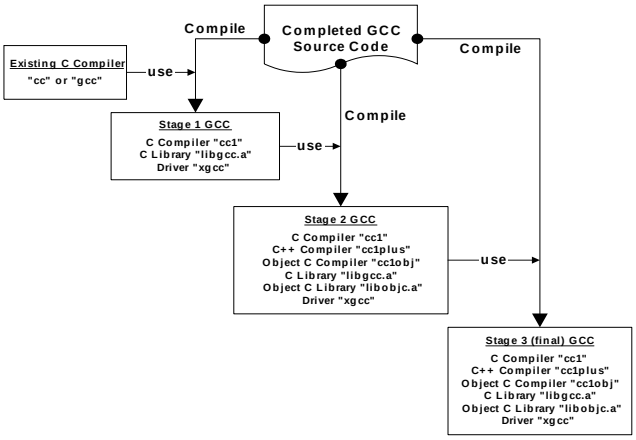
- Bootstrapping
  - Cross-platform compilation
  - Generation of VMs/interpreters for "special languages"
- Build-time component installation
- Runtime library optimization
  - VIM
- Misc. *ad hoc* hacks

Build-time view schema



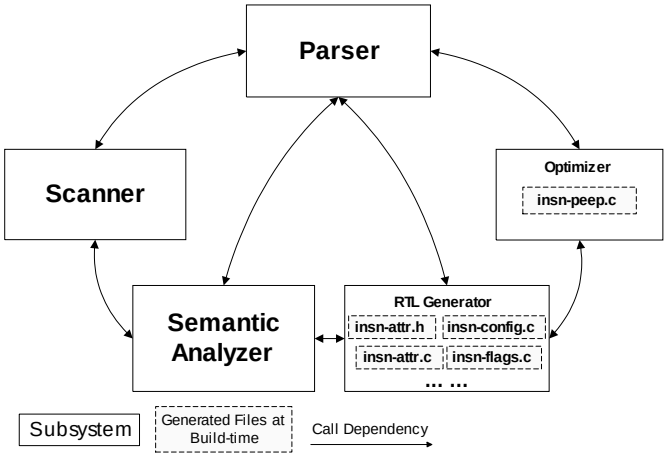
Example 1: GCC bootstrapping

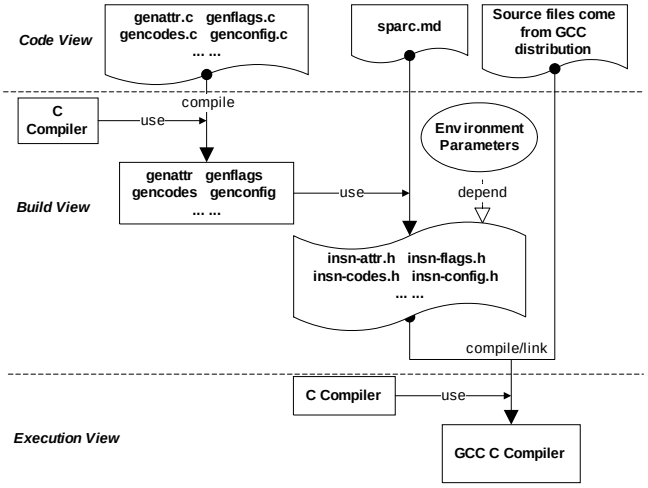
- Same source code is compiled multiple times
  - Each time by a different compiler!
    - Usually, the one built during the previous iteration.
  - Different source modules are **`include`**d and configured differently for some iterations
- Static analysis (reading) of the **`Makefile`**s doesn't help much in understanding what's going on.
  - **`Makefile`**s are templated, control flow depends on complex interactions with environment.
  - Need to instrument and trace executions of build process, build visual models for comprehension



Example 2: GCC build-time code generation

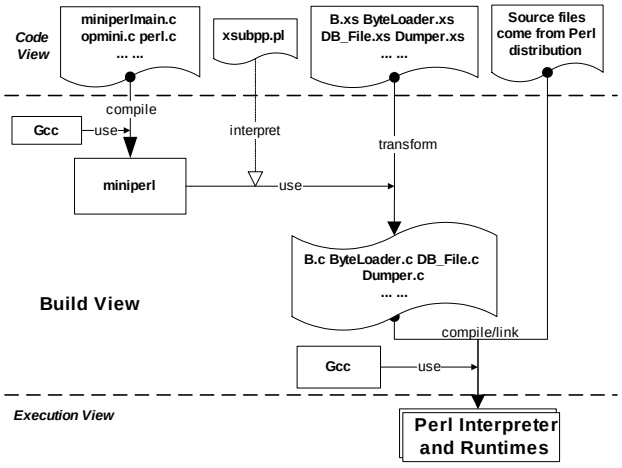
- In GCC, the common intermediate representation language (*i.e.*, post-parsing) is called the Register Transfer Language (RTL)
  - The RTL is hardware dependent!
  - Therefore, the code that generates and transforms RTL is also hardware dependent.
- RTL related code is generated at build-time
  - Information about the target environment is input as build parameters.





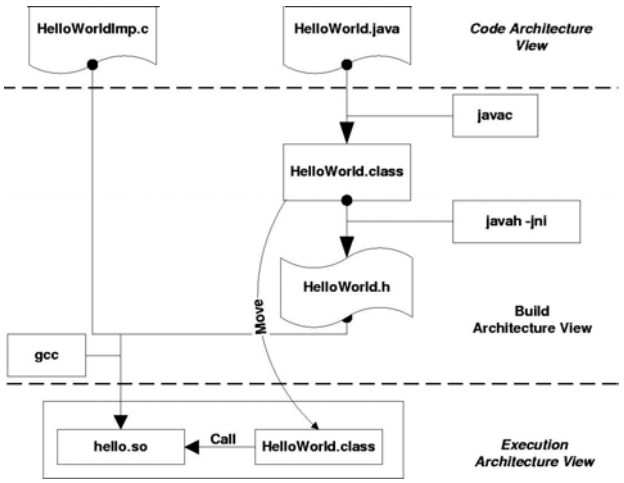
Example 3: PERL building procedures

- PERL build process exhibits both *bootstrapping* and *build-time code generation*.
  - The PERL build process is so complex that is an open source project in its own right!
- Templates written in XS language are transformed at build-time to generate C files that bridge PERL runtime with Unix runtime libraries.
  - These C files are OS dependent.



Example 4: Use of Java Native Interface (JNI)

- May want your Java program to make use of an existing C/C++ program for performance or other reasons.
- Need to go through several steps to customize the interaction between the two systems.
  - Similar to Perl XS mechanism, but done for each Java application that requires access to “native” code



"Code Robot" architecture style

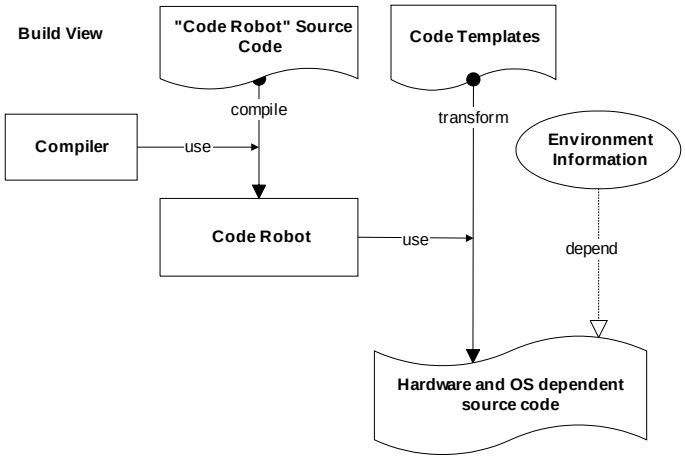
- An *architectural style* is a recurring abstract pattern of high-level software system structure [Shaw/Garlan]

"Code Robot"

Problem: – desired behavior of software depends heavily on hardware platform or operating systems.

Solution: – create customized "source" code at build-time using auto code generator, code templates, other environment-specific customizations.

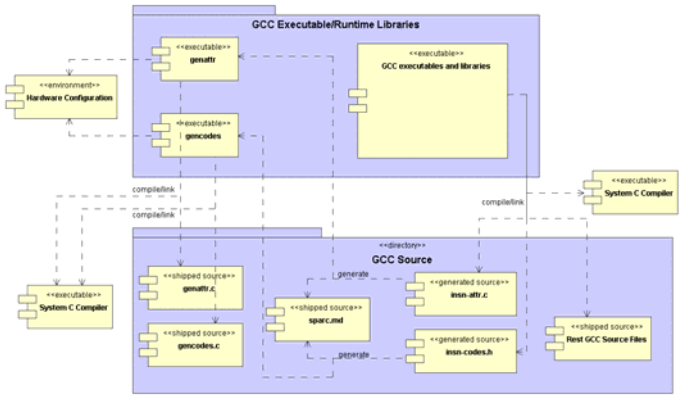
Examples – some open source systems (*e.g.*, GCC, PERL)



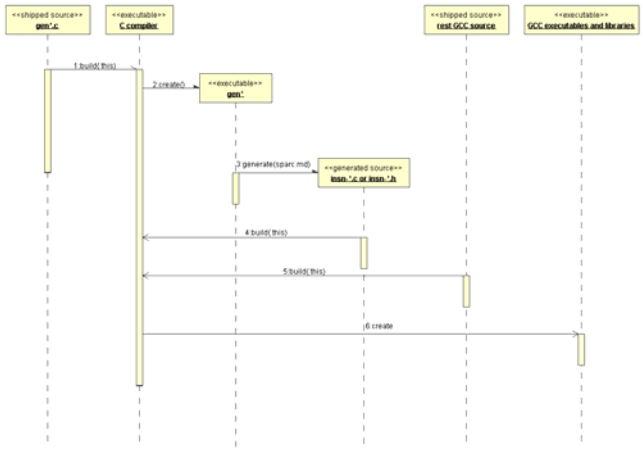
UML Representation

- Static View (UML Component Diagram)
  - Components:
    - Code written at development phase
    - Code generated at build time
    - Library and executables
    - Environment information
  - Relations:
    - Compile/Link
    - Generate
- Dynamic View (UML Sequence Diagram)
  - Model dynamic build procedures

Static UML View



Dynamic UML View



Common reasons for interesting build-time activities

- System building is simply a complex process
- Software aging
  - Older systems gather cruft which is most easily dealt with by build-time hacks
  - Native source language no longer widely supported
  - Ports to new environments dealt with at build-time
- Complex environmental dependencies which must be resolved by querying the target platform
  - Especially true for open source software
  - Common for compiler-like applications

Conclusions

- Build-time view captures interesting structural and behavioral properties of some classes of software.
- Can aid program understanding by instrumenting build tools and creating explicit build-time models
  - UML component and sequence diagrams can be used
- "Code robot" architectural style
  - Common in systems with interesting BTVs
- Future work:
  - More case studies and exploration of problem space
    - Discover recurring patterns of build-time activities
  - Develop tools to (semi) auto-extract and create build-time views