Multi-View Architecture Description and Enforcement

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ABSTRACT
In software development, implementation strays from the intended architecture in what is known as architectural drift as programmers introduce communication pathways between components that shouldn’t be interacting. In our approach, we have embedded an architecture description language (ADL) into a programming language that restricts resource access with capabilities and generates connections via metaprogramming. Not only does this ensure that the system semantics reflect its architectural principles, but this also facilitates editing compatible with rapid software evolution.

CCS CONCEPTS
• Software and its engineering → Software organization and properties; Software system structures;

KEYWORDS
Software architecture, architecture description language

1 INTRODUCTION
Software architecture allows programmers to reason about systems and create coherent designs consistent with project demands [3]. Complex architectures are often described with multiple views. Common architectural views include a module view of relationships between units of functionality, a component-and-connector (CnC) view of runtime entities and interactions, and a deployment view of component configurations and allocations [2]. The separation of concerns afforded by views can also ease software evolution. In today’s languages, an architectural change entails modifying multiple files. However, integrating architecture and semantics could localize such changes and streamline software evolution.

As software evolves, it is common for programmers to violate the intended architecture by introducing unintentional interactions between components. These dependencies are generally created when programmers can make arbitrary connections between components and access libraries which provide unrestricted use of system resources. Take, for instance, a three-tier system; it is not uncommon for programmers to make direct connections between the client and database, bypassing the server. After several iterations of such changes, the architectural drift results in software that bears little to no relation to the conceived architecture [11].

In this work, we propose an architecture description language (ADL) that prevents structural violations of the intended architecture by incorporating the architectural specification into the software implementation.

2 APPROACH
We implemented this ADL in the context of the Wyvern programming language. Wyvern was designed to enable programmers to express and enforce design constraints [10, 12]. In the CnC view of our ADL, systems are described using standard architectural notions such as components, connectors, ports, etc [2]. Consider the client-server system whose architecture is shown in Figure 1. This system would be described as follows in our ADL:
To implement a system using our ADL, programmers must supply implementations of the components by providing a corresponding module definition for each component type. The component ports reflect the dependencies of the modules. Since the Client component declares a getInfo port that requires the CSIface interface, the Client module takes in a corresponding argument. Likewise, since the Server component sendInfo port provides the CSIface interface, the Server module exposes a CSIface field.

```scala
module def Client(getInfo: CSIface): TCPClient
  def start(): Unit
  getInfo.getVal("key")

module def Server(): TCPServer
  def getVal(key: String): String
  database.get(key)
```

To prevent unintended component interactions, our system does not leave the creation of connections up to the programmer. Instead, they are assembled at runtime with their implementations derived from the architecture. This is done via metaprogramming, wherein Wyvern types can contain metadata declaring methods that are run at compile time. Our ADL uses methods in the connector type’s metadata to create component connections at compile time.

```scala
type JSONWebCtr
  val host : String
  val port : Int
architecture ClientServer
  components
  Client client
  Server server
  connectors
    JSONWebCtr jsonCtr
  attachments
    connect client.getInfo and server.sendInfo with jsonCtr
```

Since our approach groups relevant concerns into multiple architectural views, it is easier to make certain modifications. For example, if a connector is changed, only the CnC view must be modified. No change has to be made to the implementation since the connections are generated based on the architecture description. Take for instance changing a client-server connection using a JSON protocol to one using a Simple Object Access Protocol (SOAP). This would normally involve changes across multiple files. Furthermore, it is difficult to ensure that all relevant changes were addressed. The same modification in our system would be limited to changes in the CnC view alone. Thus, by automatically handling connector creation, we definitively construct component interactions in terms of the ADL specification and preserve architectural integrity across system modifications.

## 3 RELATED WORK

Many existing formal ADLs have sufficient complexity to describe software systems and their structural constraints but lack an integrated method of enforcing these properties [4–7]. A few ADLs such as ArchJava can check and enforce architecture in implementation but do not address communication through the runtime system [1]. Techniques such as reflexion models support conformance checking between the static architecture and the implementation [9]. However, reflexion models require the programmer to map elements of a high-level model to the source code. This process can be tedious and error-prone, especially for large systems.

## 4 CONCLUSION

Consistency between software semantics and architecture is important in software development—not only for protection against hazardous dependencies and structural vulnerabilities, but also for traceability in large systems. We can protect against the introduction of component interactions that violate the architectural specification by constructing a system that derives its connector implementation from the architecture in a capability-safe language. Moreover, our use of multiple architectural views allows high-level changes to be made to software in a simple, concise way. Our implementation of a multi-view ADL incorporating the capability safety of Wyvern and its application on a client-server network system demonstrates its potential for the development of larger, complex software systems that are architecturally sound.

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REFERENCES


