Can Domain-Specific Languages Be Implemented by Service-Oriented Architecture?

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Domain-Specific Languages

- A Domain-Specific Language (DSL) is a programming/modeling language that shields accidental complexity by uplifting the abstraction layer to a higher level.
- A DSL introduces domain-specific constructs and notations to facilitate productivity, reliability, maintainability and portability.
- Decision, analysis, design and implementation patterns have been identified to assist DSL developers in when and how to develop a DSL.
- Example DSLs include:
  - Robot language: An imperative DSL that controls a (Lego® Mindstorm® NXT) robot to move in different directions and distances.
  - PPCea: An imperative DSL that controls parameter settings to balance an evolution process toward optimization and convergence.
  - Feature description language (FDL): A declarative DSL to configure combinations of features.

Current Challenges

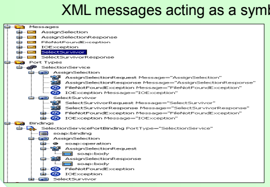
- When implementing a DSL, several obstacles have appeared due to frequent need to represent changes in domain concepts. These obstacles are especially critical for DSLs following the interpreter and compiler implementation patterns.
  - Extension/Evolution: When domain concepts change, then the lexical, syntactical and/or semantic domain constructs need to evolve. Yet, such evolution is tedious and error-prone. For example, one new domain statement or one new grammar production introduced will affect an existing DSL implementation at the lexical, syntactical, and semantic levels in different magnitudes.
  - Interoperability: A DSL is usually implemented by one base language (e.g., Java). What if it is desired to implement a DSL in different base languages? How would these base languages communicate with each other?
  - Tool Support: When a new DSL is introduced, corresponding DSL tools should be supported. Otherwise, the DSL will have fewer opportunities to be adopted. Yet, such a need requires a great amount of endeavor and promotion.

DSL Implementation Methodologies

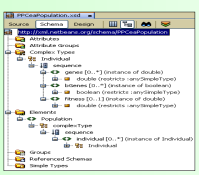
- There has been no DSL developed using SOA yet.
- AMMA is a platform to implement text-based DSLs using a Model-Driven Engineering approach that is focused on model transformations.
- The Generic Modeling Environment (GME) is a metamodeling toolkit for developing graphical DSLs. MetaEdit also provides similar functionalities.
- Six DSL implementation patterns are identified:
  - Interpreter/compiler patterns utilize the traditional compiler/interpreter techniques; (b) Embedding patterns introduce new DSL constructs from an existing General-Purpose Language (GPL); (c) Preprocessor patterns translate DSL constructs into a base language; (d) Extensible compiler/interpreter patterns add DSL optimization rules and code generation in the existing compiler/interpreter of a GPL; (e) Commercial off-the-shelf patterns utilize existing tools and/or notations for a specific domain; and (f) A Hybrid pattern is the combination of all of the above.
- There are many other implementation methodologies for DSL (e.g., Visual Studio DSL tools and MetaEdit+).

SOA approach for PPCea

- PPCea utilizes `if-else`, `while`, assignment and DSL statements to dynamically control parameters of Evolutionary Algorithms on-the-fly.
- WSDL is an automatically generated web service specification:
  - It comprises lexical and syntactical information and semantic specification of a web service.
  - For a SOA-based DSL, WSDL can assist with lexical analysis and syntax analysis.
- An XML schema describes the structure and data types of an XML message.
  - It is utilized to validate if an XML message consumed by a web service follows the specified structure and data types.
  - For a SOA-based DSL, XML schema is used to validate if XML messages acting as a symbol table contain valid data.



WSDL of a "Select" web service for PPCea

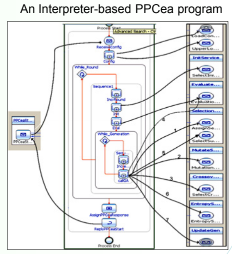


XML schema for PPCea

- WS-BPEL is an executable language to specify the interactions among web services.
  - It has various programming constructs to describe the execution flow of a business process.
  - For a SOA-based DSL, WS-BPEL describes logical and issues that may emerge in a DSL program.
- W3C defines a web service as "a software system designed to support interoperable machine-to-machine interaction over a network."
  - For a SOA-based DSL, a web service describes the semantics of a DSL statement.
  - SOA-based PPCea defines Initialize, Select, Mutate, Crossover Evaluate, Update and Entropy web services to adaptively obtain optimal solutions of an evolution process.

```
genetic
  Round := 50;
  r := 0;
  while ( r < Round ) do
    g :=0;
    tmp := 1.0;
    init;
    while ( g < Maxgen ) do
      pm := (1.0 / 1250.0) + (0.0042 / tmp);
      callGA;
      tmp := tmp * 2.0;
      g := g + Epoch
    end;
    r := r + 1
  end
end genetic
```

An Interpreter-based PPCea program



A SOA-based PPCea program written in WS-BPEL

Discussions

- Lexical Analysis and Symbol Table:
  - There is no need to perform lexical analysis: WSDL can be regarded as the lexical analyzer.
  - Symbol table functionality cannot be achieved easily. XML message passing between web services is an alternative.
- Syntactical Analysis
  - WS-BPEL specifications have defined grammars. Reinventing SOA-based DSL grammars and parsers for PPCea and FDL (and even the Robot language) are not needed.
  - Yet, WS-BPEL's great flexibility may be also misused and can result in potential pitfalls.
- Semantics and Type Checking
  - Domain-specific statements are wrapped as one or more web services.
  - Implementation of DSL web services is not much different except:
    - An internal commonly shared symbol table is no longer valid. Investigation on analyzing the scope of domain-specific parameters is needed – only those that will be needed by most web services will be encapsulated in XML messages.
    - There is a need to introduce efficient marshalling and unmarshalling algorithms to parse the aforementioned XML messages. JAXB is a more formal approach: an XML schema is used to validate and convert between objects and XML instances. Conversely, StAX is a more casual but efficient way that processes XML as a stream and ignores tree construction.

SOA Approach for FDL

- A Feature Description Language (FDL) is a declarative language that textually describes feature diagrams for domain analysis.
- The language introduces *all-of*, *one-of*, *more-of* and *optional* feature operations to explore all possible configurations along with *requires*, *excludes*, *include* and *exclude* constraints to reduce the possibilities.

```
1 Car : all (carbody, Transmission, Engine, Horsepower, opt(pullsTrailer))
2 Transmission : one-of (automatic, manual)
3 Engine : more-of (electric, gasoline)
4 Horsepower : one-of (lowPower, mediumPower, highPower)
5 include pullsTrailer
6 pullsTrailer requires highPower
```

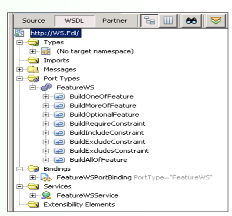
An Interpreter-based PPCea program

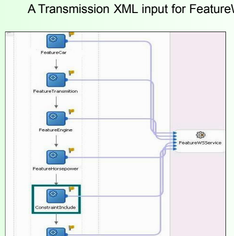
- A SOA-based FDL language introduces two web services as DSL statements:
  - *FeatureWS* comprises the aforementioned eight operations, each of which consumes previously generated and current XML messages and returns a new combinatory XML message based on normalization, variability, expansion and satisfaction rules.
  - *CompileWS* prints out the final combinatory result of all possible alternatives.
  - A preprocessing step is also needed to convert the above program to XML messages line-by-line.

- Similar to the SOA-based PPCea:
  - WSDL acts as a lexical analyzer and assist with syntax analysis.
  - XML schema validates XML messages.
  - Web services specifies DSL semantics.
  - WS-BPEL describes the execution flow of domain-specific web services to be consumed.

```
<?xml version="1.0" encoding="UTF-8"?>
<FDL xmlns:ns2="http://xml.netbeans.org/schema/FDL_Test_v2 FDL_Test_v3.xsd">
    <featuresList>
        <feature featureName="Car" featureType="all-of">
            <compositeFeature isOptional="false">Transmission</compositeFeature>
            <atomicFeature isOptional="false">carbody</atomicFeature>
        </feature>
        <feature featureName="Transmission" featureType="one-of">
            <atomicFeature isOptional="false">automatic</atomicFeature>
            <atomicFeature isOptional="false">manual</atomicFeature>
        </feature>
    </featuresList>
</FDL>
```

A Transmission XML input for FeatureWS





A SOA-based FDL program

```
*****************************
Constrained Version
*****************************
one-of (all (carbody, pullsTrailer, manual, highPower, gasoline, electric)
, all (carbody, pullsTrailer, manual, highPower, electric)
, all (carbody, pullsTrailer, manual, highPower, gasoline)
, all (carbody, pullsTrailer, automatic, highPower, gasoline, electric)
, all (carbody, pullsTrailer, automatic, highPower, electric)
, all (carbody, pullsTrailer, automatic, highPower, gasoline)
)
      </result>
    </FdlBpel_v2ProcessResponse>
  </part>
</outputVariable>
```

Output of the FDL program: Six constrained car alternatives

Conclusion

- SOA-based DSLs offer five implementation advantages:
  - SOA addresses the extension and evolution problems at syntactic and semantic levels: For new, existing extended, or evolved DSL constructs, syntactic evolution can be done by automatically generated WSDL files, and semantic evolution is achieved by introduction and/or composition of web services.
  - SOA offers interoperable communications among Web services implemented in different languages, which addresses interoperability concerns of DSL implementation.
  - WS-BPEL is a technology-neutral language that has been adopted by many vendors. It may reduce the effort to introduce tools for new or existing DSLs.
  - SOA offers improved modularization at the lexical, syntactical and semantic levels.
  - Lexical and syntax analyses adopting an interpreter or compiler-based DSL implementation are no longer needed in SOA-based DSLs.
- SOA-based DSLs may raise potential research interests to overcome the tradeoffs surrounding the flexibility of WS-BPEL grammars, WS-BPEL usability, bottlenecks on XML parsing time, and exposed domain-specific parameters.