Composition and Semantic Enhancement of Web-Services: The CASHerW-s Project

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1 Introduction

CASHerW-s is an ongoing research project looking at the composition of semantic web-services via workflow-oriented orchestrations. We have chosen to look first at OWL-S [BHL04] as it has sensibly taken out the core features needed in a workflow language for orchestration and given two existing forms of workflow semantics, as can be seen in [AHS02] and [NM02]. Our aim is to give another form of semantics, in a style which can be efficiently implemented, analysed and extended, courtesy of the principal of compositionality. We do this via an intermediate syntax in an extension to the process calculus CaSE [NLM03], which we call CaSHer-W-NUtS.

Formally speaking, we take compositionality to mean that — according to our semantic function \( \semantics \) mapping OWL-S, via our process calculus, to a labelled transition system semantics, and some notion of semantic equality, \( \semantics[t_1; t_2] = \semantics[t_1] \mid \semantics[t_2] \) and furthermore that \( \semantics[t_1] = s \implies \semantics[t_1; t_2] = s \mid \semantics[t_2] \). The reason this is such an important property of semantics is that this allows a semantic model to be built by composition alongside the definition of syntax, for instance in an interactive editor, as well as being the enabling property of semantics for modular analysis. We claim that no semantics currently defined have this property.

Furthermore we will define an extension to OWL-S called CASHerW-s, with part of our motivation being to introduce purely functional language extensions [Nor04]. The orchestration engine is being developed in the purely functional language Haskell [Jon03], and should be able to execute any workflow whose semantics can be described in the process calculus. We thus envisage in the future the creation of orchestration semantics for ontologies such as WSMO [FB02].

Along with the engine, an editor is being produced, which diagrammatically represents an OWL-S workflow using an extended fragment of the UML Activity Diagram notation. We believe it is important to use a graphical notation familiar to engineers, rather than invent a new one. This takes the form of a plug-in for Eclipse, a popular open-source development environment.
2 Representation

While the syntax represented in the OWL-S ontology is appropriate for the storage and communication of a workflow, it does not represent the way such a design is built in an editor. In particular, to compose the performance of a new process in an existing context, i.e. building a composite process, all previous performances have to have been defined along with their complete workflow, with no possibility to extend this, if the current syntax is used as a model. To increase the utility of compositionality within our semantic translation, we choose to abstract out the connections so that these can be interleaved with the performances they connect within those process types that allow such communication.

\[
\text{Process ::= AtomicProcess } m \text{ AProcess} | \\
\text{CompositeProcess } m \text{ CProcess} \\
\text{ConsumeList ProduceList} \\
\text{CProcess ::= \text{Sequence PerformanceList} } | \\
\text{Split PerformanceList} | \\
\text{SplitJoin PerformanceList} | \\
\text{Any-Order PerformanceList} | \\
\text{ChooseOne PerformanceList} | \\
\text{IfThenElse Performance Performance} | \\
\text{RepeatWhile Performance} | \\
\text{RepeatUntil Performance} \\
\text{Performance ::= Perform } n \text{ Process DataAggregation} \\
\text{Connection ::= Connect } n_1, c, n_2, a, j \\
\text{PerformanceList ::= Performance} | \\
\text{Performance; (PerformanceList)} | \\
\text{Connection; (PerformanceList)} \\
\text{DataAggregation ::= ValueDataList} \\
\text{ValueCollectorList} \\
\text{ValueDataList ::= () | a; (ValueDataList)} \\
\text{ValueCollectorList ::= () | a, k; (ValueCollectorList)} \\
\text{ConsumeList ::= () | a, n, b, j; ConsumeList} \\
\text{ProduceList ::= () | c, n, d; ProduceList} \]

Table 1. The OWL-S Process Type

We have therefore created, as shown in Table 1, a representation of OWL-S in which composite processes\(^1\) depend on performances\(^2\) whose declared dataflow has only two components: value data declarations, as before, and what we have called value collectors. A value data list just names which inputs\(^3\) are provided by constants. A value collector allows the representation of a value function, but only declares how many components are needed, \(k\), not where they come from. In the absence of an explicit value collector declaration, an input is assumed to have a singleton component.

\(^1\) Note that the names of processes are ranged over by \(m\).  
\(^2\) Note that the names of performances are ranged over by \(n\).  
\(^3\) Note that the names of inputs are ranged over by \(a\) and \(b\), and outputs \(c\) and \(d\).
Connections are represented as first class members of the performance lists in the body of composite process declarations. Note that those composite processes without a performance list do not allow communication between their component parts. Each connection names the performance, $n_1$, providing the output, $c$, as well as which component, $j$, of which input, $a$, of which performance, $n_2$, expects the values. In this way new connections can be composed with existing performances and the compositionality of our semantic representation extends to this. Note further that a compositional translation from the existing OWL-S representation to this model is possible since a performance can be immediately followed by the complete set of connections according to its value sources and value functions.

In manipulating the syntax, we have also taken the opportunity to add an explicit consume operator, which acts as the complement of the produce operator. Implicitly ConsumeLists both name the inputs, $a$, of the composite process, as in the OWL-S syntax, and at the same time the components, $j$, of the inputs, $b$, of the component performance, $n$, they provide. The symmetrical nature of the produce operator avoids the need to overload the typing of the connections; value source and value function declarations are used in OWL-S with a dummy 'parent perform' variable, even though a process communication is what is actually being implied.

CaSE is a conservative extension of CCS [Mii89] dealing with multi-party synchronizations, which represents the flow of time as abstract clock ticks. These are governed by maximal progress, meaning that internal action is prioritized over, and preempts, the advance of time. CaSE has been used to provide semantics for dataflow-oriented software composition [NF04]. We believe that by extension it can be used to provide a compositional model for web-service orchestration. However, our approach needs both ticks respecting maximal progress and a looser version in which maximal can be bypassed. CaSHEW-NUsS is a further conservative extension to CaSE which expands the transition labels in the operational semantics with the notion of indexed clocks. This index is used to differentiate between clocks for which the transitions respect the properties of maximal progress and determinism, and those which do not. One motivation behind this extension was the provision of semantics for the split operator in OWL-S. The split operator completes when each subprocess is scheduled for execution, and, thus, the clock signaling completion of the process has to tick, despite the presence of the remaining internal work still to be achieved in the encapsulated performance.

3 Implementation

Using inductive data-types we have a direct representation for OWL-S and CaSHEW-NUsS processes. In functional style we can then perform a direct implementation of the mathematical translation between the two, that will be described in this work, as well as the operational semantics for CaSHEW-NUsS.
Inputs, outputs and explicit silent actions, at the implementation level, can be bound to IO actions, which allows the calculus to call atomic web-services and execute inline Haskell code. OWL-S already allows the insertion of expressions written in an external syntax to be bound to control points, for example in valueFunctions and if-then-else conditions. As a result, it is our aim to allow the insertion of arbitrary, well-typed Haskell expressions at these points. In order to facilitate this, we are implementing a Haskell evaluation web service, which takes serialized input, executes the expression and returns serialized output.

In conjunction with the CASheW-s project, we are also working on expanding the existing libraries provided by the HAIFA\(^4\) project; a library from our previous work for implementing Web-Services in Haskell. Included in HAIFA is a Generic XML Serializer, which allows serialization of Haskell data with minimum intervention from the programmer, a SOAP/1.1 implementation, a web-service publisher and a simple HTTP server, on which the orchestration engine will be based. Currently, the work in this area primarily focuses on creating an implementation of XML Schema [TBM+01] in Haskell, so that XSD types used in an ontology can be directly imported for use in a workflow.

In providing this language to the end-user we allow the tree structured data typical of XML to be processed easily for the purpose of mediation and so on. Haskell, being a purely functional language, explicitly distinguishes between what are pure functions, that is computations which only depend on the inputs supplied, and side-effecting computations, which can be effected by the IO monad [Wad90]. This allows a greater degree of safety in executing workflow code, and when working with pure functions only, the behaviour of a piece of code can be guaranteed. All IO sections can also be explicitly guarded with try/catch blocks in order to improve run-time safety and make a programs behaviour fully predictable. Furthermore, potentially harmful behaviour exhibited by code which effects the world can be restricted and potential security holes reduced, a concept very important in the world of the semantic web. Together with the process calculus semantic rules, it should therefore be possible to provide formal semantics for how a given workflow should behave, right down to the grounding level, with the only uncertainty being the behaviour of the servant network and hardware.

We use Haskell as an implementation and mediation language for the reasons of safety already mentioned, but also for many of its unique qualities. Being a lazy language, it natively provides an ideal platform on which to construct code incorporating the complex recursive data-structures presented by RDF and XLink, rather than placing reliance on the termination of a link sequence. This allows Haskell to intrinsically deal with infinitely expanding XML trees. Higher-order polymorphic functions will also enable a more abstracted and modular way of combining mediators. We also envisage that Haskell will lend itself to a straightforward implementation of the partition refinement algorithm, capturing the calculus' behavioural equivalence theory and thereby allowing diagnosis of deadlocks etc.

\(^4\) The HAIFA project page can be found at http://savannah.nongnu.org/projects/haifa
4 Editing

Our editor, as an Eclipse plug-in, allows for the parsing, serialization and visual manipulation of OWL-S constructs. Eventually, the editor will also allow the serialized OWL-S to be passed directly to the engine for execution, via the use of an appropriate web-service. In addition, the notion of extension points, common within the Eclipse environment [GB04], will be utilised to mirror the extension points seen within the OWL-S syntax. Notably, the editor will allow the handling of value functions via this mechanism. There is current work in restricted extensible settings like Protegé [Ele04] and other early work in Eclipse from CMU, but it is not clear that either is working with the aim of being extensible, as we plan. When extended as a CASHeW-s editor these functions will be written in Haskell. Our implementation of this functionality will centre around the editor's communication with a Haskell evaluator web-service. The user will be able to enter Haskell functions and have them validated by this service. This process also ensures that the function is well-typed, and that this property extends to the surrounding workflow. Once the feasibility of this approach is validated we should like to establish a formal type-theory including a suitable Haskell fragment; that [AHS02] is already based in Haskell semantics suggests that this would be a promising approach.

As well as being able to integrate Haskell functions into an OWL-S workflow, we will also build a CASHeW-s ontology of mediators, which will contain semantically annotated Haskell functions, enabling mediation between XSD data-types grounding concepts within a workflow. The editor will be capable of looking up functions in this ontology, and inserting them at appropriate points in the workflow.

In this presentation, we will review the CaSHeW-NUtS process calculus, formally describe the translation of OWL-S into this language, describe its implementation and sketch the architecture by which the resulting engine interacts with our editor.

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