Chapter 6

Conclusion

This thesis looked to a future where services are ubiquitous. The many different types of services that will be available and the different contexts they will apply to, means that although some common services will have "standard interfaces" many more services will be developed by individual service providers that reflect their own needs, abilities and constraints. This diversity creates three problems that have been addressed.

Firstly, to address the problem of unambiguously describing data so that mutual understanding can span organisational and cultural boundaries, a means to "globalize" data definitions was proposed. Outsourced types are a solution to the problem of shared understanding of data.

Secondly, to address the problem of dynamically discovering services that can solve problems a structure for describing what services actually do and the results or effects they deliver was proposed. Capability descriptions are a solution to the problem of describing services to allow discovery.

Lastly, to address the problem of communication between services that have no prior agreements in place regarding the syntax, semantics and sequencing of the data they exchange a mechanism was proposed for guided interaction. This mechanism is a solution to the problem of ad hoc interaction between services and their clients.

6.1 Evaluation

In section 1.6 suggested several criteria were suggested for evaluating solutions to the problems of ad hoc interaction between services. In this section the work presented in this thesis is evaluated against these criteria.

All of the solutions presented in this thesis are presented at a *conceptual* level and in sufficient detail to allow them to be readily implemented in web enabled languages such as XML, XML Schema and OWL as well as programming languages such as Java.

Outsourced types are described as a conceptual meta model. The meta model describes *what* is necessary for shareable data descriptions rather than specifying

how they should be constructed. This was done because the concept of globalized data descriptions is new, and it was necessary to describe what is required *in addition* to typical or "local" data descriptions for shared understanding between heterogeneous services.

Capabilities are not described at the same level because they are based on previous work in verb and action description. Consequently, there was less need to define *what* should be described than to describe *how* the previous work could be used in the context of capability descriptions for web based service discovery.

The major elements of the Guided interaction mechanism are also described in conceptual models. The mappings from the conceptual models (message, obligation, expectation, instruction, and item) to the CPN ML constructs used in the implementation show one way the conceptual models may guide an implementation.

All the proposals allow developers to create *expressive* service descriptions. Guided interaction in particular, because it is based on implementation independent communication abstractions, allows the description of capability plans for many different types of services in simple or complex interaction scenarios.

The interaction plan language allows the specification of variations in behaviour based on the competency and resources of service clients. This makes interaction plans fault tolerant and adaptable.

One of the advantages of the plan language is the ability to incorporate subdialogues that are modeled in exactly the same way as main dialogues. This facility provides a natural and expressive way of composing capabilities. Combined with a facility for calling external services the plan language provides a means for clean and achievable web service composition.

What has not been dealt with is how constraints on the reactive behaviour of participants can be specified. The example used in section 1.6 was "answer questions about the price but do not tell the maximum price we will pay". Although constraints of this nature are necessary, it is more appropriate to define them at the application level rather than the level of the interaction mechanism.

The *formal* foundation for all of the proposals presented in this work is provided by ORM and its associated CSDP, and CPNs. ORM and CPNs both have a formal basis.

The solutions proposed are *comprehensible*. One of the motivations behind these proposals was to avoid using complex formal languages and techniques to ensure the solutions were easy to understand and intuitive for a wide range of users. Capability descriptions and Guided interaction in particular, build on existing solutions and well understood concepts to ensure they are practical and easy to use.

It has been demonstrated that Guided interaction is an *executable* specification with the implementation using CPN Tools. The guide can execute any capability plan that is well formed. The interaction mechanism can execute these plans to provide goal satisfying service to service interaction without human involvement at runtime. The mechanism allows developers to build in error handling by specifying alternate paths for processing or delivering context sensitive error reports to clients.

The solutions proposed in this thesis are *suitable* for services operating in the web environment. Outsourced type and capability descriptions are based on information found in web based information sources. It has been demonstrated how conceptual models can be mapped into machine accessible languages such as XML and OWL for use on the web.

Guided interaction provides a robust and flexible means for services to interact with one another in a loosely coupled manner. Loose coupling has been ensured by focussing on reducing the information a client needs to know before interacting with a service provider. The guide mechanism allows both parties to retain autonomy and self control within an interaction by providing the means to request actions and to refuse to perform them if appropriate.

The existence of web based message exchange mechanisms is assumed, but there is no reliance on or use of WSDL. This is because the WSDL specifications are not suitable for loosely coupled ad hoc interaction.

6.2 Discussion

Outsourced types are a novel approach to data description for web applications. In developing this specification the concern was with ensuring that existing specifications, standards and definitions could be utilised in the definition of shared data. The Outsourced types proposal also provides the means to identify instances of object types in a global context by linking an instance's identity to the relevant identity scheme.

The association of capabilities with outsourced types is a way of attaching functional requirements to ORM models. This is similar to the way UML interfaces can specify the methods that must be provided by an implementation of the interface. In the outsourced types definition the capabilities represent activities that can be associated with instances of the type such as creation and modification.

The conceptual model of information sources is a useful device for describing web based resources. The model uses the lexical, semantic and logical mappings discussed in section 1.4.1 to the conceptual model. One issue that has been sidestepped is the difference between "equivalent" and "same as" information sources. The information source model uses "is equivalent to" to mean "can be substituted for". In OWL, the property "same as" represents substitutability whereas "equivalent" is effectively used to mean "exactly the same".

The role names used to describe the relationships between objects in the conceptual models are based on the ORM preference for human readable fact types rather than references to meta data schemes, such as Dublin core. An interesting avenue for further work with outsourced types is to find a concrete representation that can use external meta data schemes as proposed for application profiles. In this way a data model could use public definitions to describe objects and public meta data elements such as "dc:publisher" to describe the nature of the relationships between them.

Capabilities provide a description of the action, context and effects of services. The preference here is to describe capabilities from an action in context point of view, but there are also convincing arguments for describing capabilities in terms of their effects. Although the means to describe capabilities in both ways has been incorporated, the perception of effects and side effects is dependent on the context of the client, whereas the "action in context" perspective provides a more independent view of what services do.

After completing the work on guided interaction with its built-in facility for disambiguation, there seems to be less need to describe the parameters a service can accept in the capability description. It would seem to be more useful to focus on describing the actions, context, output and effects of a capability rather than the inputs. This is because the number, type, and kind of inputs could vary depending on the needs of the provider delivering the capability.

Guided interaction is a mechanism for service interaction that provides a new interaction language that is designed to reflect the input mechanisms that are commonly used and well understood in computer interaction.

One of the important ideas in this thesis is the intuition that the flow of a conversation is driven by what the provider still needs to know, which is in turn, dependent on what information each client has been able to provide so far. Each client proceeds along a conversation path that depends upon their ability to supply what the service needs. This confirmed our suspicion that pre-defined shared conversation protocols are not suitable for ad hoc interaction, because they do not provide the flexibility required to support clients with different sets of resources.

The guide, implemented in CPN Tools, is effectively a command interpreter so rather than producing a Petri net for every conversation [43], there is one Petri net that can run any capability plan. Another advantage of the implementation is that it can easily run multiple concurrent conversations.

Ad hoc interaction cannot be both effective and efficient in the way that pre-programmed interactions with interfaces can. Guided interaction sacrifices some efficiencies to allow software clients' access to previously unknown services without the overhead of runtime computational complexity. Clients with prior knowledge of, or experience with, a service would not necessarily need to use guided interaction.

An important avenue for further work is the investigation of the cost and complexity of outsourced types, capability descriptions and guided interaction. The cost of creating outsourced type descriptions and capability descriptions falls with each service developer and tools could be developed to make these descriptions easier to construct. It would be reasonable to assume that many of these descriptions would be reusable.

Assessing the cost of guided interaction is more complex. There are issues of where the complexity lies, with the client or the service, and whether the complexity is dealt with at design/development time or at runtime. To begin to quantify the issues requires an estimate of the cost of development of all clients of all services, versus the cost of development of the interface that interacts with a guide (i.e. once for all developers). However, the runtime cost of multiple messages in a dialogue

with the added cost of disambiguation must also be taken taken into account in the guided case. For some applications there is also a trade-off between the cost of no interaction (where dynamically found services cannot be used because clients lack the programming to do so) and the cost of engaging in a dialogue in order to successfully complete an interaction.

The guide mechanism allows different services, providing the same capability, to present the capability in the way that suits them best. It also allows different views of the underlying functionality to be presented to clients. This gives services the ability to differentiate themselves for competitive advantage.

By deliberately focussing on ad hoc interaction without humans in the loop, a language for interaction has been created that makes it much easier for services to interact with people and vice versa. At present there is no mechanism available that would let a web service seek further information from clients (human or otherwise). The interaction language defined here allows service requests to be easily transformed into visual elements for human consumption such as text boxes, list boxes and menus.

In this thesis three problems associated with ad hoc interaction between web services have been addressed. Outsourced types, capability descriptions and guided interaction are offered as innovative and practical solutions to these problems.

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Appendix A

Information source in OWL

```
<?xml version="1.0"?>
<rdf:RDF
    xmlns="http://a.com/ontology#"
    xmlns:protege="http://protege.stanford.edu/plugins/owl/protege#"
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
    xmlns:owl="http://www.w3.org/2002/07/owl#"
    xmlns:daml="http://www.daml.org/2001/03/daml+oil#"
    xmlns:dc="http://purl.org/dc/elements/1.1/"
  xml:base="http://a.com/ontology">
  <owl:Ontology rdf:about="">
    <owl:imports rdf:resource="http://purl.org/dc/elements/1.1/"/>
    <owl:imports rdf:resource="http://protege.stanford.edu/plugins/owl/protege"/>
    <owl:imports rdf:resource="http://www.w3.org/1999/02/22-rdf-syntax-ns"/>
    <owl:imports rdf:resource="http://www.w3.org/2002/07/owl"/>
    <owl:imports rdf:resource="http://www.w3.org/2000/01/rdf-schema"/>
  </owl:Ontology>

  <owl:Class rdf:ID="InformationSourceType"/>
  <owl:Class rdf:ID="Source"/>
  <owl:Class rdf:ID="Organisation"/>
  <owl:Class rdf:ID="InformationSource">
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:onProperty>
          <owl:ObjectProperty rdf:about="#controlledBy"/>
        </owl:onProperty>
        <owl:maxCardinality rdf:datatype=
            "http://www.w3.org/2001/XMLSchema#int">1</owl:maxCardinality>
      </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:onProperty>
          <owl:ObjectProperty rdf:about="http://purl.org/dc/elements/1.1/publisher"/>
        </owl:onProperty>
        <owl:maxCardinality rdf:datatype=
            "http://www.w3.org/2001/XMLSchema#int">1</owl:maxCardinality>
      </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:onProperty>
          <owl:ObjectProperty rdf:about="http://purl.org/dc/elements/1.1/publisher"/>
        </owl:onProperty>
        <owl:minCardinality rdf:datatype=
            "http://www.w3.org/2001/XMLSchema#int">1</owl:minCardinality>
      </owl:Restriction>
```

```
    </rdfs:subClassOf>
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:onProperty>
          <owl:ObjectProperty rdf:about="#controlledBy"/>
        </owl:onProperty>
        <owl:minCardinality rdf:datatype=
            "http://www.w3.org/2001/XMLSchema#int">1</owl:minCardinality>
      </owl:Restriction>
    </rdfs:subClassOf>
  </owl:Class>

  <owl:ObjectProperty rdf:ID="synonymOf">
    <rdfs:domain rdf:resource="#InformationSource"/>
    <rdfs:range rdf:resource="#InformationSource"/>
  </owl:ObjectProperty>
  <owl:ObjectProperty rdf:ID="isOf">
    <rdfs:domain rdf:resource="#InformationSource"/>
    <rdfs:range rdf:resource="#InformationSourceType"/>
  </owl:ObjectProperty>
  <owl:ObjectProperty rdf:ID="partOf">
    <rdfs:domain rdf:resource="#InformationSource"/>
    <rdfs:range rdf:resource="#InformationSource"/>
  </owl:ObjectProperty>
  <owl:ObjectProperty rdf:ID="moreSpecific">
    <rdfs:domain rdf:resource="#InformationSource"/>
    <rdfs:range rdf:resource="#InformationSource"/>
  </owl:ObjectProperty>
  <owl:ObjectProperty rdf:about="http://purl.org/dc/elements/1.1/publisher">
    <rdfs:range rdf:resource="#Organisation"/>
    <rdfs:domain rdf:resource="#InformationSource"/>
  </owl:ObjectProperty>
  <owl:ObjectProperty rdf:ID="contains">
    <rdfs:domain rdf:resource="#InformationSource"/>
    <rdfs:range rdf:resource="#InformationSource"/>
  </owl:ObjectProperty>
  <owl:ObjectProperty rdf:ID="controlledBy">
    <rdfs:domain rdf:resource="#InformationSource"/>
    <rdfs:range rdf:resource="#Organisation"/>
  </owl:ObjectProperty>
  <owl:ObjectProperty rdf:ID="equivalentTo">
    <rdfs:domain rdf:resource="#InformationSource"/>
    <rdfs:range rdf:resource="#InformationSource"/>
  </owl:ObjectProperty>

  <owl:DatatypeProperty rdf:ID="typeName">
    <rdfs:domain rdf:resource="#InformationSourceType"/>
    <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#FunctionalProperty"/>
  </owl:DatatypeProperty>
  <owl:DatatypeProperty rdf:ID="id">
    <rdfs:domain rdf:resource="#Organisation"/>
    <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#FunctionalProperty"/>
  </owl:DatatypeProperty>
  <owl:DatatypeProperty rdf:ID="name">
    <rdfs:domain rdf:resource="#Source"/>
    <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
  </owl:DatatypeProperty>

  <owl:FunctionalProperty rdf:ID="uriref">
    <rdfs:domain rdf:resource="#InformationSource"/>
    <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#anyURI"/>
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
  </owl:FunctionalProperty>

  <InformationSourceType rdf:ID="IdentityScheme"/>
```

```
  <InformationSourceType rdf:ID="Ontology"/>
  <InformationSourceType rdf:ID="CodingScheme"/>
  <InformationSourceType rdf:ID="Standard"/>
  <InformationSourceType rdf:ID="Entity"/>
  <InformationSourceType rdf:ID="ServiceDescription"/>
  <InformationSourceType rdf:ID="Capability"/>
  <InformationSourceType rdf:ID="Thesaurus"/>
  <InformationSourceType rdf:ID="Specification"/>
  <InformationSourceType rdf:ID="Taxonomy"/>
  <InformationSourceType rdf:ID="Glossary"/>

  <InformationSource rdf:ID="exchangerate">
    <partOf>
      <InformationSource rdf:ID="wordnet">
        <controlledBy>
          <Organisation rdf:ID="princeton">
            <id rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
              Princeton
            </id>
          </Organisation>
        </controlledBy>
        <uriref rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
          www.cogsci.princeton.edu/webwn2.0
        </uriref>
        <isOf>
          <InformationSourceType rdf:ID="Dictionary"/>
        </isOf>
        <dc:publisher rdf:resource="#princeton"/>
        <contains rdf:resource="#exchangerate"/>
      </InformationSource>
    </partOf>
    <dc:publisher rdf:resource="#princeton"/>
    <controlledBy rdf:resource="#princeton"/>
    <uriref rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
      www.cogsci.princeton.edu/webwn2.0?word=exchange+rate
    </uriref>
  </InformationSource>

  <InformationSource rdf:ID="iso8601">
    <controlledBy rdf:resource="#iso"/>
    <uriref rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
      www.iso.ch/iso/en/datesandtime</uriref>
    <isOf rdf:resource="#Standard"/>
    <dc:publisher rdf:resource="#iso"/>
  </InformationSource>

  <Source rdf:ID="XMLSchema">
    <name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">XMLSchema</name>
  </Source>
  <Source rdf:ID="WordNet">
    <name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">WordNet</name>
  </Source>
  <Organisation rdf:ID="iso">
    <id rdf:datatype="http://www.w3.org/2001/XMLSchema#string">ISO</id>
  </Organisation>
  <Organisation rdf:ID="w3c">
    <id rdf:datatype="http://www.w3.org/2001/XMLSchema#string">W3C</id>
  </Organisation>
  <Source rdf:ID="ISO8601">
    <name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">ISO8601</name>
  </Source>
</rdf:RDF>
<!-- Created with Protege (with OWL Plugin 1.2 beta, Build 139)
     http://protege.stanford.edu -->
```

Appendix B

Example data for a currency conversion service

Base name	*Alternative name*	*Source*
Convert		www.unspsc.org **84121605** Currency conversion service
Convert		virtual.cvut.cz/ kifb/ convert&lang=en
	Exchange	virtual.cvut.cz/ kifb/ exchange&lang=en
	Change	virtual.cvut.cz/ kifb/ change&lang=en
amount		www.cogsci.princeton.edu/webwn2.0&word =amount
		dictionary.reference.com/search?q=amount
		virtual.cvut.cz/ kifb/ amount&lang=en
		virtual.cvut.cz/ kifb/ amount_of_money&lang=en
	value	www.cogsci.princeton.edu/webwn2.0&word =value
	value	dictionary.reference.com/search?q=value
	value	virtual.cvut.cz/ kifb/ value&lang=en
	value	virtual.cvut.cz/ kifb/ economic_value&lang=en
	sum	virtual.cvut.cz/ kifb/ sum&lang=en
	sum	virtual.cvut.cz/ kifb/ sum_of_money&lang=en
from		dictionary.reference.com/search?q=from
	source	www.cogsci.princeton.edu/webwn2.0&word =source
	source	dictionary.reference.com/search?q=source
	origin	www.cogsci.princeton.edu/webwn2.0&word =origin
	origin	dictionary.reference.com/search?q=origin
	origin	128.136.11.20:8080/sigma/skb=SUMO_skb&term=origin
to		dictionary.reference.com/search?q=to
	target	www.cogsci.princeton.edu/webwn2.0&word =target
	target	dictionary.reference.com/search?q=target
	destination	www.cogsci.princeton.edu/webwn2.0&word =destination
	destination	www.cogsci.princeton.edu/webwn2.0&word =destination
	destination	dictionary.reference.com/search?q=destination
	destination	128.136.11.20:8080/sigma/skb=SUMO_skb&term=destination
	into	dictionary.reference.com/search?q=into
currency		www.iso.ch/iso/en/prods-services/popstds/currencycodes.html
		www.xe.com/iso4217.html
		www.bsi-global.com/Technical\%2BInformation/Publications/tig90x.doc
		www.daml.ecs.soton.ac.uk/ont/currency.daml
		128.136.11.20:8080/sigma/skb=SUMO_skb&term=currency
		virtual.cvut.cz/ kifb/ currency&lang=en

Figure B.1: Alternative sources of information for the conversion capability.

Appendix C

Model with Restart, Cancel, Pause and Resume

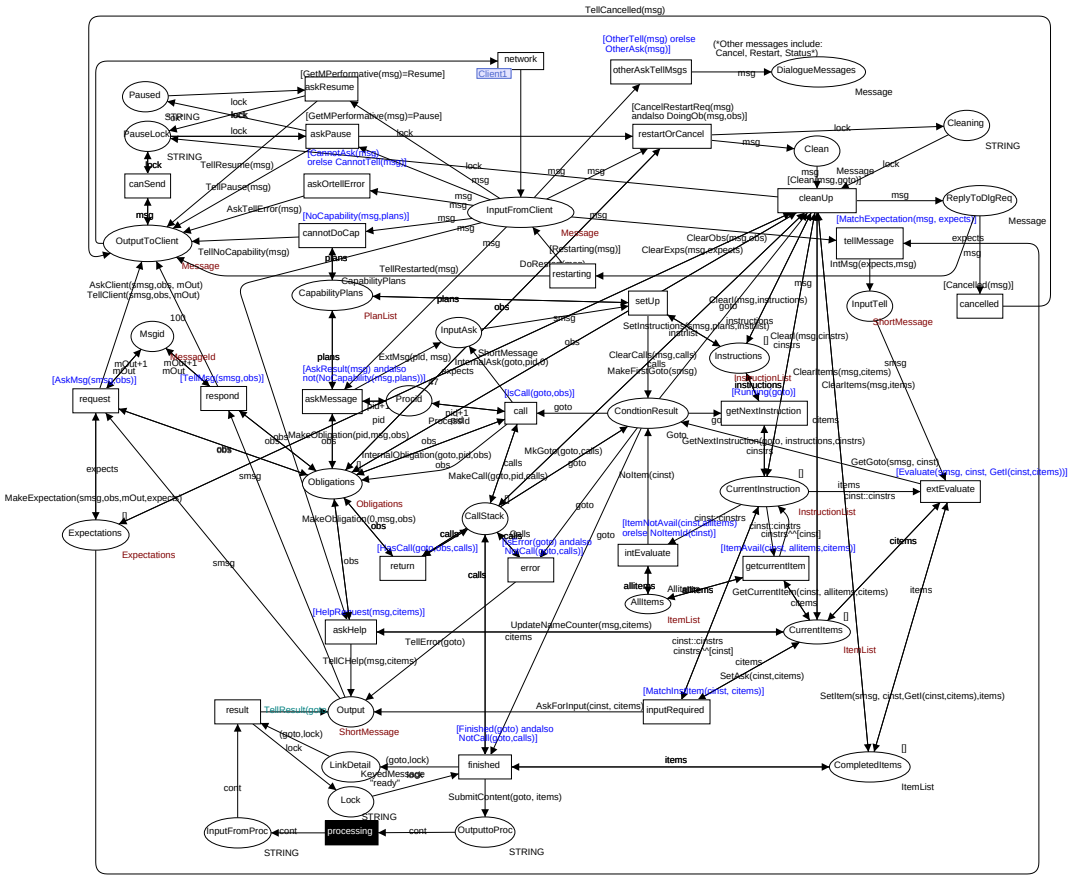

Figure C.1: Service Provider

Vita

Publications arising from this thesis include:

Oaks, P. (2003), Towards Self-Describing Web Services. In *International Conference on Web Engineering (ICWE 2003).* Oviedo, Spain.

Oaks, P. and ter Hofstede, A. and Edmond, D. and Spork, M. (2003), Extending Conceptual Models for Web Based Applications. In *The 22nd International Conference on Conceptual Modeling (ER 2003).* Chicago, USA.

Oaks, P. and ter Hofstede, A. and Edmond, D. (2003), Capabilities: Describing What Services Can Do. In *The First International Conference on Service Oriented Computing (ICSOC 2003).* Trento, Italy.

Permanent Address: Faculty of Information Technology
Queensland University of Technology
Australia

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[1] LaTeX 2_ε is an extension of LaTeX. LaTeX is a collection of macros for TeX. TeX is a trademark of the American Mathematical Society. The macros used in formatting this thesis were written by Glenn Maughan and modified by Dean Thompson and David Squire of Monash University.