A Multi-Responsive Communication Architecture for Web Service Description and Discovery

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ABSTRACT
The discovery of suitable web services is a demanding challenge for organisations that plan to benefit from this technology. Markedly even more so when strategic objectives, organisational structures, business processes and technology are situated in a climate of constant change; such dynamic conditions have an impact upon the normative behavioural patterns of people working in organisations. Based upon the principles of the Pragmatic Web, this paper reveals a mechanism that captures behavioural patterns as affordances and norms that when merged form a multi-responsive communication architecture. Enhancing the traditional two-role conversational model found within the Language Action Perspective, the multi-responsive communication architecture placates web service discovery in settings where diverse and unpredictable organisational contexts coupled with the need to consider the actions of all participants that influence the selection of web services are accounted for.

Categories and Subject Descriptors
D.2.1 [**Requirements Specification**]: Reusable Software – *web services.*

General Terms
Semiotics.

Keywords
Pragmatic Web, Semiotics, Speech Acts, Norms, Web Services.

1. INTRODUCTION
The Pragmatic Web will in the future provide the means to identify and consume contextually relevant web services. However, the challenge to achieve this aim requires competencies that move beyond the current boundaries of syntactic and semantic web technology, particularly when organisations are predisposed to an assortment of dynamic conditions that web technology presents. Dynamic conditions encompass strategic objectives, organisational structures, business processes, and technology [6, 8, 33] that when situated in a climate of constant change impact the normative behavioural patterns (norms) of people working in organisations.

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1.1 Research Problem
Conventional syntactic web service description, based upon the Web Service Description Language (WSDL 1.1) standard is used to list definitions for data types, message types, port types (operations) and bindings [48] whilst focusing upon communication protocols that enable packets of data as Simple Object Access Protocol (SOAP) messages to traverse network architectures [42]. Conventionally, a web service provider publishes a web service(s) in a registry [15, 36]. The registry provides the references to the web services available and links to description files. The bind details of the web service enable a web service provider and consumer to have some kind of interaction based upon the SOAP protocol [23, 25]. Semantic Web Services (SWS) illustrate syntactic web services with additional semantic mark-up that exemplifies ontological descriptions of data and processes. Cardoso [11] describes ontology linked to SWS as a strong form of semantics, where relationships, constraints, and rules governing the use of use of data are present. WSMO [50], WSDL-S [49] and OWL-S [34] are prime examples. Occasionally some semantic annotations [34, 49, 50] surface when searching for web services, but in practice these are a rarity [9, 27, 35, 41]. Furthermore, as WSDL is the current standard, such ontology languages are often implemented with WSDL as the starting point.

An aim of the Pragmatic Web is to "enhance human collaboration with techniques for ontology negotiations and pragmatic ontology-building efforts in communities of practice" [40]. This aim requires the creation and exchange of all types of signs present in syntactic and semantic descriptions between web service providers and consumers [30, 41]. Identifying web services that are contextually relevant highlights four challenges that should be considered if the ideas of the Pragmatic Web are to be executed:

1. The syntactic representations in a WSDL 1.1 file must be made available in a shared vocabulary that is both accessible and modifiable by web service providers and consumers.
2. Strong semantic descriptions may prohibit identifying web services that contextually fit an organisation. For example, a shared vocabulary arranged in a taxonomic scheme that facilitates the active creation and sharing of signs between web service and providers may be more appropriate when considering the dynamic conditions of organisations.
3. Hinged upon the creation and exchange of all types of signs that either point to existent things within a web service or symbolic signs conveying a law like interpretation of syntactic and semantic descriptions, authors such as [16, 28, 29] that have used semiotics to understand web services have

not used the detail related to various types of signs nor the associated process of semiosis.

4. Communication in syntactic and semantic web service discovery contexts typically start after the publication of a web service, leaving a service consumer to speculate about the appropriateness of a web service. Dialogue is insufficient when the dynamic conditions related to organisations must be shared across organisational boundaries.

1.2 Proposed Solution

To achieve the first three challenges listed above, Peircean semiotic theory takes a favourable position. Peirce's particular semiotic theory of signs is applicable to web service description and discovery due to its triadic grounding. According to [2, 12, 13, 18, 37] Peirce's version of semiotics is general (it accounts for the emotional, practical and intellectual experience of sign users), triadic (owing to the three foundational philosophical categories that Peirce created namely, firstness, secondness and thirdness), and pragmatic (in that it takes into consideration the dynamic context in which signs are produced and consumed in). Semiotic theory is used to assess the availability of syntactic and semantic web service description, first in a Pragmatic Web context, and second, according to the sign classifications in a process of semiosis. Joint action to facilitate the sharing of a vocabulary between web service providers and consumers is also defined in accord with semiosis. To address that last challenge, a multi-responsive communication architecture, Benfell and Liu [5], is built upon to further enhance the dialogue component of web service description and discovery. It draws upon 'communication loop theory' found in work by [17, 32, 39, 47] but circumvents its limitations in relation to the capture of 'trans-situational grounds' [21]. Such grounds are social phenomena brought into the current conversational situation that affect speech act composition; they are the representation of the dynamic conditions that affect organisations that must be sought when opting to use a particular web service.

2. SEMIOTIC THEORY

In developing a theory of signs, Peirce [37] said that a sign is anything that stands for something (the object) to somebody (the interpretant). Peirce's unique semiotic theory of signs is applicable to characterising the signs exchanged between web service providers and consumers:

Firstness	**Secondness**	**Thirdness**
Qualisign (*A quality*)	**Sinsign** (*An existent thing*) A WSDL file, an OWL-S file	**Legisign** (*A convention or law*) Description file syntax containing: operation, data type etc
Icon (*A similarity*)	**Index** (*Causal connection*) A web service. An actual operation. An actual data type. Proper noun – an object.	**Symbol** (*Refers to its object by convention or law*) Operation naming convention. Data type conventions.
Rheme (*Quality only – a common noun*) Class names. Data type variables: age for example.	**Dicent** (*An sign of actual existence – a sentence*) The web service used for a general task, an actual operation invoked for a sub task and trans-situational grounds forming dynamic conditions.	**Argument** (*An inference from dicent signs in context*) Trans-situational grounds representing norms embedded inside an affordance. Deontic actions inferred from dynamic conditions based upon trans-situational grounds.

Table 1. A Semiotic Analysis of Web Services

Owing to three foundational philosophical categories that Peirce created namely, firstness, secondness and thirdness, it also draws together three terms that constitute a sign: representamen; object; and interpretant. Peirce generated various semiotic accounts specifically, 'early', 'interim' and 'final' and in each case semiotic theory becomes more developed. The following texts describing Peircean semiotic theory [2, 12, 13, 18, 37] places syntactic and semantic web service technology into the semiotic framework in table 1 derived from [4].

2.1 Shared Semiosis and Joint Actions

Based upon the findings in Table 1, a unifying paradigm that draws web service providers and consumers into joint actions [10, 24] is defined next. To achieve this objective, Stamper's work on ontology and affordance is used. Stamper [43, 44] recognises three different types of ontology, whereby the first relates to the recognition of symbols typically found in any standard presentation format, and the second identifies distinct objects and object type classification. The second type of ontology typically denotes indexical-sinsigns, indexical-legisigns and symbolic-legisigns. It suggests a taxonomic scheme of web service elements, as opposed to strong semantic descriptions, being more applicable to third type of ontology acknowledged by Stamper [43, 44]. The third type of ontology, affordance, is particularly relevant to web service description and discovery in a Pragmatic Web setting as it is based upon the view that the world known to a person consists of only the actions a person can carry out in that environment [19]. The purpose of identifying 'affordance' is to provide the contextual setting for web service description and discovery for all interpretant signs. At an abstract level an affordance shares similarities with business capability modelling, Ulrich [45]. Web services are deployed in activity orientated situations, and people carry out activities commensurate with their expected duties, defined here as multi-responsive actions. The formalised structure of shared semiosis in table 2, based upon [31], sets the configuration of the multi-responsive communication architecture.

Semiotic branch	**Intent and Real World Effect**	**Shared Semiosis**
Syntactic Encoding. (Denotative)	Capture through existing texts the elements to form codes that structure the syntactic and taxonomic features of a web service description file.	**Representamen – intertextuality and encoding.** Source code, analysis and design specifications – narrative and diagrammatic models.
Semantic Encoding. (Denotative)	Comprehension by consensus (dynamic objects) the web service elements symbolised as codes in relation to their functions and capabilities that belong to an affordance.	**Dynamic object – negotiated code and reading.** Taxonomic descriptions linked to contextualised interpretation by all participants.
Pragmatic All interpretant signs. (Connotative)	Linking the interpretations of the codes with potential contexts and effects on all participants and specifying a meaning of all codes congruent with all participants.	**Final interpretant – (argument-symbol-legisigns)** Linked to the dynamic conditions of an organisation captured in affordances and structured using norms amplified using modal operators to indicate the appropriateness of a web service.

Table 2. Shared Semiosis

The syntactic encoding (representamen) of a web service description file must first be agreed between web service providers and consumers (sinsigns and legisigns). Stamper's

second type of ontology complies with the specification of indexical-sinsigns, indexical-legisigns and symbolic-legisigns as a taxonomic scheme. Rhemes classify instances of operations and data and identify the data types used. Dicent signs complete the taxonomic scheme by cataloguing the functionality of a web service linked to each entry in the shared vocabulary. Not until argument-symbol-legisigns are inferred as multi-responsive actions, and embedded into an affordance, can web service discovery be fully achieved. An affordance is therefore 'complete' when syntactic, semantic and pragmatic descriptions are present relating to a web service. However, the dynamic conditions linked to an organisation may invoke changes in an affordance, so any changes are recorded in a chronological order related to new trans-situational grounds and the revised multi-responsive actions that follow. Final interpretant signs (argument-symbol-legisigns) are the fusion of dicent signs, dynamic conditions (collectively known as legal and social norms that are captured as trans-situational grounds) and the resultant actions that can be taken when inferred from dynamic conditions.

3. DEONTIC REPRESENTATION OF TRANS-SITUATIONAL GROUNDS

Trans-situational grounds (dicent signs) are social phenomena brought into the current conversational situation that affect speech act composition [1, 38]; they represent the dynamic conditions affecting organisations that must be sought when opting to use a particular web service. Endorsed in this paper is the view that 'communication agents' (responsible for describing or selecting a web service) engaging in dialogue must know of any trans-situational grounds for web service utilisation to be a success. Goldkuhl [21] refers to this notion as 'memory traces' and cites [20]. Capturing trans-situational grounds classifies web service providers and consumers as multi-participants in joint actions. Trans-situational grounds collectively represent legal norms [7, 26] that are owned by an organisation, which by nature are independent of any participant. They may also be documented as textual entities which according to [14] can exhibit agency. Trans-situational grounds may also be captured as social norms [46] that may not be documented but are known jointly by people in multi-participant settings. Legal and social norms that constitute trans-situational grounds must be made available when considering web services in a dialogue framework, either represented in a norm-base in a textual format to expose agency or communicated in speech acts. As trans-situational grounds are situations that are brought into a current conversational context, a multi-responsive action is a response by a communication agent to earlier actions made by other people. A multi-responsive action (argument-symbol-legisign) is a regulated action, such as obligation, permission, forbidden or release from obligation inferred from trans-situational grounds immediately present in a conversational context.

3.1 Applying deontic logic

Deontic Mental Model (DMM) theory by Beller [3] is based upon the premise that people behave according to known social restrictions on actions. DMM theory suggests that people's understanding of norms follow two principles, first that interpretation of the deontic actions forbidden and obligation are *closed-world*: facts supporting a deontic action must be integrated, and in combination must be *exhaustive*, and second they are *equivalent*: if facts are met (or not met) a deontic action can be inferred. A person can deduce from a set of facts a deontic action to be taken, and in reverse the implied facts are derived from a specific deontic action. In the multi-responsive communication architecture, a communication agent would solicit the dynamic conditions as trans-situational grounds (facts) and infer from them the deontic action to be taken, thus a deontic regulated action is a multi-responsive action. DMM theory is also based upon the assumption that people relate each relevant action (normative behaviour) with all the dynamic conditions (facts). Three models must be present to satisfy the multi-responsive communication architecture: conditions that describe the expected functionality (*F*) of a web service, dynamic conditions (trans-situational grounds) as legal norms (*L*) or social norms (*S*) and Deontic Regulated (*DR*) actions that represent multi-responsive actions. For instance, before a service consumer agent chooses to select a web service according to a *DR* action, a communication agent accesses the shared vocabulary to determine compliance of a web service with a functional specification (*F*), for example, that for successful selection of a web service it must calculate UK tax:

UK tax only:	UK Tax only ↔ permission (to use the web service)
For permission to use a web service, UK tax only…….	**Sufficient and necessary to fulfil an affordance**
	Inference:
Calculates UK tax only	yes
Not UK tax only	no
Reformulation (as a deontic action ***argument-symbol-legisigns***)	Permission: If calculates UK tax only, then permission to use web service.
	Obligation: If calculates not UK tax only, then obligation not to use web service.

Table 3. Functional Specification

The communication agent seeks a response related to all dynamic conditions belonging to a web service from all participants before making a decision, and obtains as a dynamic condition (trans-situational ground) a legal norm that states: web services *must* only be used from trading partner X:

UK tax only and Trading partner X:	(UK Tax only and Trading partner) ↔ permission (to use the web service)
For permission to use a web service, UK tax only…….	**Not sufficient but necessary to fulfil an affordance**
	Inference:
Trading partner X	yes
Not Trading partner X	no
Reformulation (as a deontic action ***argument-symbol-legisigns***)	Permission: If UK tax only and trading partner, then permission to use web service.
	Obligation: If not UK tax only or not trading partner, then obligation not to use web service.

Table 4. Legal Norms

The service consumer agent also obtains through a speech act a dynamic condition (trans-situational ground) as a social norm that states: web services *may* be used from trading partner X or from an alternative reputable service provider:

UK tax only or reputation:	(UK Tax only and reputation) ↔ permission (to use the web service)
For permission to use a web service, UK tax only…….	**Not sufficient but necessary to fulfil an affordance**
	Inference:
Reputation satisfactory	yes
Reputation not satisfactory	no
Reformulation (as a deontic action ***argument-symbol-legisigns***)	Permission: If UK tax only or reputation satisfactory, then permission to use web service.
	Obligation: If not UK tax only or reputation not satisfactory, then obligation not to use web service.

Table 5. Social Norms

Independent dicent signs are sufficient and necessary (*F*), but when coupled with legal (*L*) or social norms (*S*) dicent signs become insufficient, as legal and social norms become necessary to fulfilling an affordance. Hence each condition (in tables 4 and 5) must be combined as a conjunction for DR actions to be taken – *closed world*. A communication agent would infer if the action is obligatory, permissible, forbidden or is a release from obligation. For example, if a trans-situational ground is represented as "the web service provider *must* have a satisfactory reputation" (dependent upon the provenance of such statement see Grice [22]) determines that a conjunction must be present between the atomic conditions in the closed world principle. Forbidden and permission, and obligation and release from obligation are pairs of contradictories. Based upon this premise, if a person is obliged to commit an action (obligation), they are forbidden to omit the action (forbidden), and if a person is allowed to commit an action (permission), it is not necessary to omit the action (release from obligation) Beller [3].

4. CONCLUSION

Proposed in this paper is an approach to web service description and discovery using semiotics and shared semiosis in joint actions to coordinate the interaction of all participants engaging with a web service. It promotes the idea of 'affordance' as a route to achieve the description and therefore discovery of web services in accord with the dynamical conditions of different organisations. The Peircean classification of signs makes up the semantic taxonomic scheme whilst communication agents query, send requests or updates participants or a norm-base that contains trans-situational grounds. Finally, web service description and discovery would include a set of affordances that describe the appropriateness of a collection of web services under a multitude of dynamic conditions as trans-situational grounds. The following observations are made:

1. Multi-responsiveness is a DR action in response to several different initiatives as memory-traces represented as trans-situational grounds;
2. Trans-situational grounds for a deontic action are brought into the current situation by a person as justification for taking action regarding the selection of a web service;
3. Trans-situational grounds (as dynamic conditions) are rule-constituting [21], which in the case for web service discovery legal and social norms are conjunctions to functional specifications. Returning to dicent signs as signs of actual existence for specific tasks enforces the notion that semantic descriptions should contain a taxonomic scheme as opposed to stronger semantic descriptions made available with ontology languages such as OWL-S;
4. A multi-responsive (deontic) action is a compound of rules (dynamic conditions) that represent dicent signs, legal norms and social norms contained within an affordance. The normalised form of arguments that make up an affordance is:

$$Argument = ((F_{\text{dicent}} \wedge (L_{\text{dicent}} \vee S_{\text{dicent}})) \leftrightarrow DR_{\text{Multi-responsive action}}$$

The conditional side of the argument can include any number functional requirements, legal norms and social norms to fulfil the DMM principles exhaustive and equivalence whilst the DR side refers to one action only.

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