Semantics Service Composition Using Conceptual Graph for Addressing Imprecise Service Requirements

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Introduction

- Web Services has become an important research topic in the fields of the Service-Oriented Architecture (SOA).
- Automatic or semi-automatic service discovery, invocation and composition techniques are on demand.
- The Semantic Web Services seems to be the most promising way towards achieving automatic or semi-automatic service discovery, invocation, and composition.

Problems

- **Insufficient usage context information**: The current work are focusing on ontology based data type semantics and do not sufficiently address how a service is fitted into its usage context.
- **Precise requirements required to locate services**: In order to locate the required services, the current work requires precise service requirements which are difficult to be specified at the preliminary stage of the service discovery.
- **Insufficient information about inter-relationship among service**: The current work has not addressed the inter-relationships among services sufficiently, which makes the service discovery in an isolated manner.

We try to describe services by

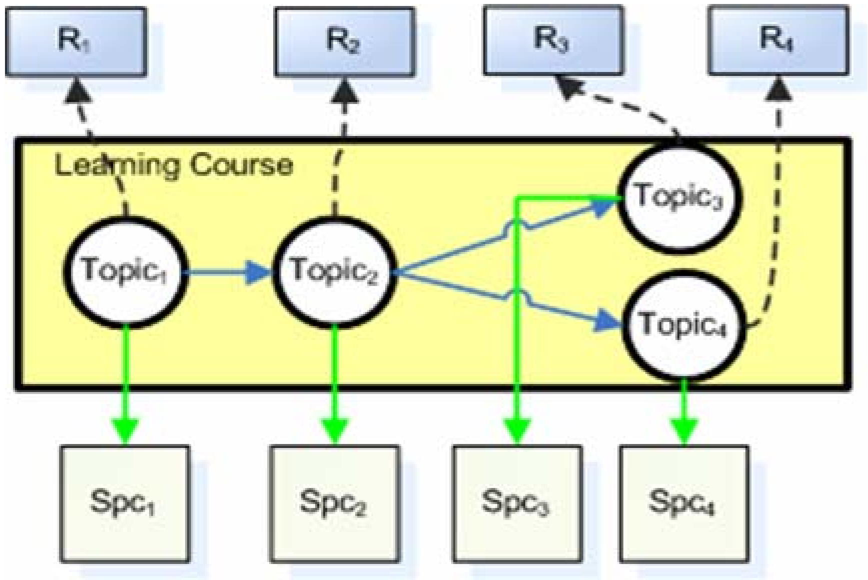
- using the inter-service relationships.
- Using the contextual information.
- so easing service composition process.

Our proposal

- A Context-based Semantic Description Framework (CbSDF).
  - To describe services by the usage context aspect using Conceptual Graphs and Spider Model.
  - To use non-monotonic rules to describe the pre-conditions and effects of services and the conditions for service composition.
  - To search for services based on imprecise service requirements.

Example: Learning Resources

- A learning flow with learning resource specifications, but not the physical resources.
- Learning resources located dynamically at learning time based on the specifications.
- The diagram illustrates a learning course with learning resource specifications. The dotted lines represent the links dynamically established at learning time



Context-based Semantic Description Framework (CbSDF)

- The proposed CbSDF consists of four components:
  – Definitions of atomic and composite services
    - By having clear definitions of atomic service and composite service, we can identify what kind of information is relevant to describing a service
  – Service Conceptual Graphs
    - Give an overall and abstract description of the relationships between services and their related concepts.
  – Semantic Service Description Model (Spider Model)
    - Semantically describes service itself and the relations with other services.
  – Non-monotonic Rules
    - Describe the pre-conditions and effects of services and the conditions for service composition.

Conceptual Graphs

- A conceptual graph (CG) is a finite, connected, bipartite graph with nodes of one type called concepts and nodes of the other type called conceptual relations
  - The label of a concept node consists of two fields separated by a colon, [*type*: *referent*] i.e. [class: instance].
  - Conceptual Relations represent the relationships between concept nodes.
- Projection of CG
  - $\pi : v \rightarrow u$, where $\pi_u v$ is a sub-graph of u called a *projection* of v in u. π is called the projection operator. v describes a more generalised concept than u, $u \leqslant v$
  - Projection concept is important in CG matching and reasoning.

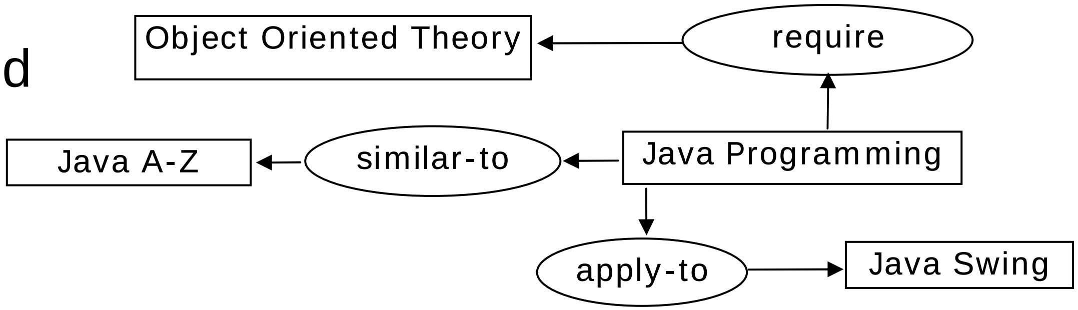
Dependency Graph of Learning Concept

- A learning concept dependency graph G_d is a CG where the concept type is restricted to concepts within the Learning Object ontology

$$G_d =< C, R, \vec{E} >, type(C) \in O$$

  - C: a set of learning concept nodes; $type(C)$ returns a set of leaf node concepts in the Learning Object ontology.
  - R: a set of relation nodes that represent the relations among learning concept nodes, including pre-requisite relation type and conceptual relation type etc.
  - $\vec{E}$: a set of arcs that associate relation nodes with concept nodes.
  - O: the Learning Object ontology.

- An example is illustrated in the diagram

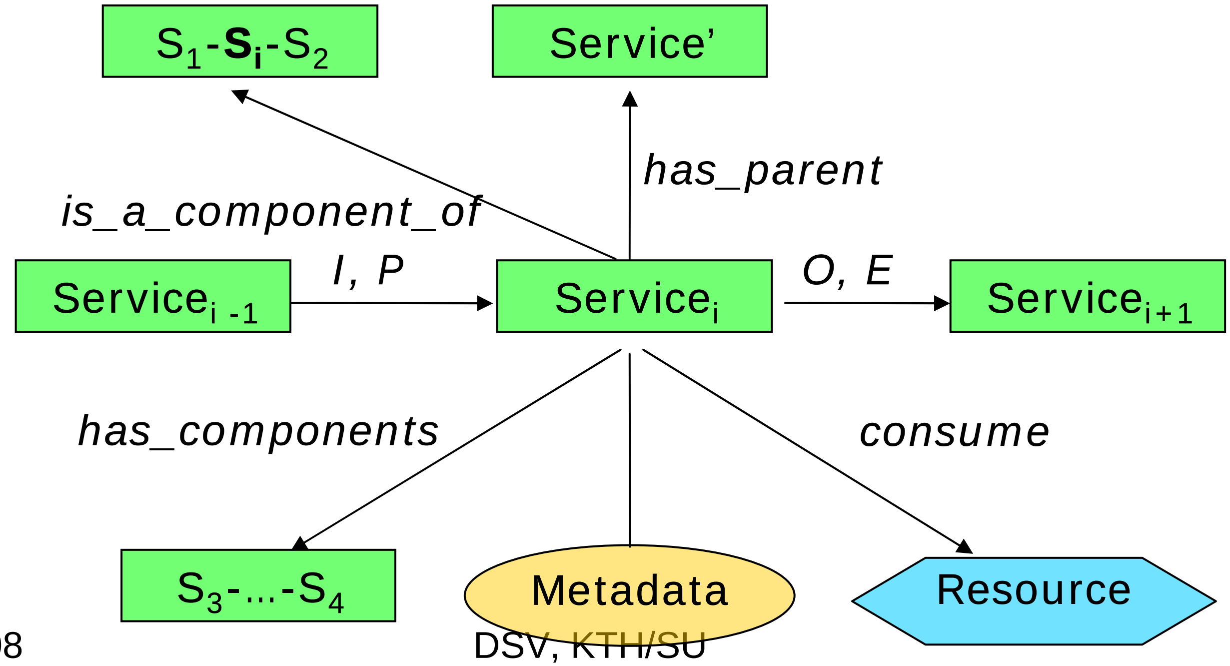


Four Types of Semantics in Web Services

- Data Semantics
  - Formal definition of data in Input and output message.
- Functional Semantics
  - Formal definition of the web service capability.
- Non-functional Semantics
  - Formal definition of quantitative or non-quantitative constraints.
- Execution Semantics
  - Formal definition of execution flow of services of a process or of operations within a service.

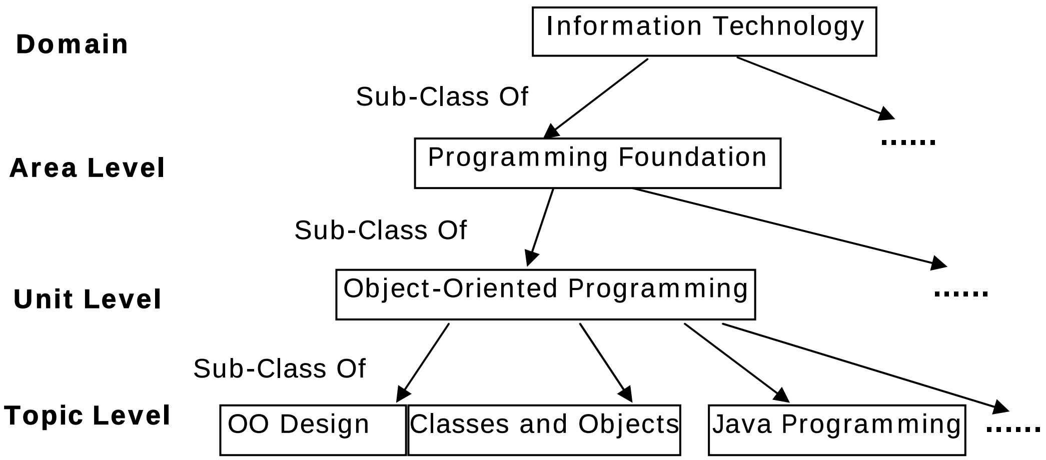
Graphical Illustration of SSDM

- The notations used in the diagram are:
  - **S_i=$Service_i$**
  - **Service'** can be either the parent or ancestor of **$Service_i$**
  - **S_1, S_2, S_3**, and **S_4** are any services.
  - ***I, P*** is the Inputs and Pre-condition, and ***O, E*** is the Outputs and Effects.



Learning Objects Ontology

- The ontology represents the concepts of Learning Objects
- Based on the ACM/IEEE Computing Curriculum.
- Three levels: Area, Unit, and Topic.
- The leaf node of the ontology is a course or part of a course that can be directly taken by learners.



Non-monotonic Rules

- Reason for using non-monotonic rules
  - Handling unpredictable situation in a open service repository.
  - Exception handling.
- The non-monotonic rules are described using Defeasible Logic. A *defeasible theory* DT is a triple:

$$DT = (F, R, >)$$

  - F: a set of facts;
  - R: a finite set of rules;
  - $>$: a superiority relation on R.
- The rules are divided into two categories:
  - General rules
  - Domain specific rules
- The rules are used in two ways:
  - Describe services pre-conditions and effects.
  - Validate service composition results: Trigger-able validation and Compose-able validation.

General Rules

- The general rules are normally used to construct and validate composite services and they are applicable to all the services, for example :
  - *r1*: if a service's pre-condition is satisfied, then normally it can be executed.

    $$satisfy(S.preCon) \Rightarrow executable(S)$$

  - *r2*: if a service is not available, then definitely it cannot be executed.

    $$\neg available\ (S) \rightarrow \neg executable(S)$$

  - *r3*: if two services are composed through input and output data flow, then normally the data types of the input and output are compatible, i.e. one is a same or sub-type of the other.

    $$composable\ (S_1, S_2) \Rightarrow type(S_1.Opt) \le type(S_2.Ipt)$$

  - The *r2* has higher priority than *r1*: *r2* > *r1*

Domain Specific Rules

- The domain specific rules are normally used to describe the pre-conditions and effects of services and can only be applied to a specific domain, for example:
  - *r1*: if the service is supplied with a valid postcode, then normally the correct result will be returned.

    $$valid\ (postcode) \Rightarrow result(S)$$

  - *r2*: if the requested address is in UK, then this service is definitely applicable.

    $$location\ (UK) \rightarrow applicable(S)$$

Two-Step Service Discovery Mechanism

- The first step is preliminary service discovery step using the CG matching technique.
  - Requirement → CG
  - Match with Service Conceptual Graphs
- The second step, validation and ranking step, is to refine the results from the first step based on the service requirements, the SSDM, and the non-monotonic rules.

CG Similarity Calculation

- A CG similarity *Sim* is calculated through concept nodes similarity S_c and relation node similarity S_r.

$$S_c = 2\left(\sum_{c \in \bigcup O} (weight(c) \times \beta(\pi_{G_1} c, \pi_{G_2} c))\right) \Bigg/ \left(\sum_{c \in G_1} weight(c) + \sum_{c \in G_2} weight(c)\right)$$

- $$S_r = \frac{2m(G_c)}{m_{G_c}(G_1) + m_{G_c}(G_2)}, \qquad Sim = S_c \times (a + (1-a) \times S_r)$$

  - $\bigcup O$ is the union of all of the common generalisation graphs of G_1 and G_2.
  - $\beta(\pi_{G_1} c, \pi_{G_2} c)$ is a function to calculate the semantic similarity between two concepts.
  - $m(G_c)$ is the number of the relation nodes in the common overlaps of G_1 and G_2.
  - $m_{G_c}(G_i)$ is the number of the relation nodes of the common overlaps in G_i and the overlaps' adjacent relation nodes.
  - a is a value between 0 and 1 representing the impact factor of S_r, which make sure that the overall similarity *Sim* will not be 0 unless both S_c and S_r are 0.

Semantic Similarity Ranking

- In the second step of the service discovery, according to the service requirement and the SSDM, the similarities between the services and the requirement are calculated.

$$sim(R, S) = \frac{\sum_{\forall \alpha \in \lambda} \omega \times dist(\alpha(R), \alpha(S))}{max(\lambda(R), \lambda(S))}$$

  - *λ*: a set of all the semantic characteristics functions.
  - *λ()*: a function that returns the number of semantic characteristics.
  - *α()*: an element of *λ* that returns a semantic characteristic which can be, e.g. an element of the metadata in the SSDM or the inputs and outputs of a service.
  - *dist()*: a function that calculate the semantic distance between two semantic characteristic and its returned value is between 0 and 1.
  - *ω*: a weight factor that specifies how important a semantic characteristic to a learner is and its value is between 0 and 1.
  - *max():* a function returns the greater of its two arguments values.
  - *R* and *S*: the service requirement and a candidate service.

Semantic Distance Calculation Methods

- Tree Based Similarity
  - the semantic similarity between two topics in a ontology is defined as a function of the meaning shared by the topics and the meaning of each of the individual topics.

$$sim(p,q) = \begin{cases} 1 & if\ type(p) = type(q)\ and\ instance(p) = instance(q) \\ depth/(depth+1) & if\ type(p) = type(q)\ and\ instance(p) \neq instance(q) \\ 2d_c/(d_p + d_q) & if\ type(p) \neq type(q) \end{cases}$$

- Semantic Cosine Similarity
  - Two items i_p and i_q are considered as two column vectors in the user requirement matrix. The similarity between items is measured by computing the cosine of these two vectors.

$$sim(i_p, i_q) = \cos(i_p, i_q) = \frac{i_p \bullet i_q}{\sqrt{\| i_p \| * \| i_q \|}}$$

Conclusion

- A Context-based Semantic Description Framework (CbSDF) is proposed for service description and a two-step service discovery mechanism for service search.
- Aiming to provide a service description framework and a search mechanism that can tolerant imprecise specified service requirements.
- The key technologies used to capture the semantics from imprecise requirements and validate the service discovery results are the CG and the non-monotonic logic, i.e. Defeasible Logic.
- Continue future research on CG and non-monotonic rules in order to improve service description, discovery, and composition techniques.
- Design a suitable evaluation model to evaluate our work.