Towards Spatio-Temporal Reasoning

Summary A

Forstadius along with his coauthors in [1] expected that the retrieval problems in WWW will persist in pervasive computing. The present service discovery systems did not utilize the context information, despite the impact caused by the spatial and temporal changes in user's context to the availability of resources. To support high-level service discovery in pervasive computing authors in [1] came up with a framework for context-aware service prioritization and RDF-based Model for Context-based Rules.

The framework classifies the discovered services into a fixed set of pre-determined classes for constructing prioritized service lists based on their description data and user profile. The user profiles are built on user's context information involving current situation and preferences and the services can be both physical equipment and WWW-based entities.

To implement the functionalities of the framework the authors present a flexible RDF-based model for Context-based rules. In the model the rules are included to RDF description of resources like users and services. Rules are constructed with two properties: Action and Condition. Action, a higher order statement "reification", comprises of subject, predicate, and object. The predicate expresses the action to be carried out only if the condition is true. A condition is true if all its component statements re true. A rule can be for example "if there is a resource, and the user at same location, and the user's status is work, and the resource is of type Projector, then recommend the resource (action)."

Summary B

The paper [2] presents an ontology-based formal context model *CONON* to address critical issues including formal context representation, knowledge sharing and logic based context reasoning. CONON is an OWL encoded CONtext ONtology for modelling context in pervasive computing environments.

The pervasive computing environments represents the collection of distinct intelligent environments that share some common features but contains detailed features for their unique identification. The model aims at extending these general concepts to multiple application specific domains. The model describes an upper context ontology to outlines common concepts about basic context and provides extensibility for adding domain-specific ontology in a hierarchical manner. The upper ontology of the model is structured around abstract entities and utilizes owl properties to associate attributes to individual physical or conceptual objects. Whereas the specific ontologies section of the model contains entries of ontology sets defining the details of these general concepts and their features in individual sub-domains.

The paper proposes reasoning that exploits first order predicates and in addition to the ontology reasoning it includes a more flexible user-defined reasoning mechanism. The equivalence of OWL and description logic extended the reasoning to other aspects of context aware computing like entailment of rules to physical location. The user defined reasoning rules enable a wide range of higher-level, conceptual context that can be deduced from relevant low-level context for e.g. Sleeping can be deduced by reasoning rules like *“(?u locatedIn Bedroom) ∧ (Bedroom lightLevel LOW) ∧ (Bedroom drapeStatus CLOSED) ➔(?u situation SLEEPING)”.*

Summary C

Liao and his coauthor in [3] realized that the context-aware reasoning cannot infer from the temporal content and thus lacks efficient detection of any potential danger or in general prediction of any event. The authors came up with a modified context reasoning model (CRM) that included the time factor and named it TempCRM.

TempCRM make use of semantic web and adds a time tuple to conventional first-order predicate for accommodating a temporal event.

Context type(<subject>, <verb>, <object>, <time>)

TempCRM is inspired by the ontology structure in [2] and therefore uses OWL specifications to define smart home ontology containing computing entity, location, person, and activity. The flexible structure enabled the ontology to be extended to a set of sub entities like a room is extended to living room, bedroom, etc. The model extends RDF context to RDF temporal context enabling the representation of the relationship among context predicate for a temporal event.

The usage behaviour of a device in smart home is modelled via probability density function that enables the generation a reasonable dangerous level. Based on the assumption that a potentially dangerous situation is consequence of a series of temporal events, the rule is defined with multiple component statements similar to rules in [1]. To optimum efficiency the reasoning engine not only executes periodically but can also be activated when a temporal event is occurred.

Summary D

The authors in [4] introduce SOWL, a high-level query language for handling ontologies analogous to relational databases. The paper also proposes a model to illustrates how spatial and spatio-temporal information and evolution in space and time can be efficiently represented in OWL. The model focuses on the representation on static and dynamic information by ontologies. To represent the dynamic features the SOWL includes the representation of temporal intervals like "before", "after", etc. and spatial relations are distinguished into qualitative (i.e. south of) and quantitative (i.e. 10km away). Furthermore, the spatial ontologies are defined using reference coordinate system.

SOWL model stands out because of its spatio-temporal reasoning support that utilize SWRL rule set on spatial (topological or directional) relations and Allen temporal rules for asserting inferred temporal relations.

The distinct and plain SOWL query language is presented for querying the SOWL model. SOWL is a high-level language the uses the basic structure of SQL language with enhancements for time and space representation. The language supports a list of Allen temporal and spatial operators like "*DURING*" and "*OUTSIDE OF*" respectively.

Discussion

The key idea of semantic web is to facilitate the working cooperation between computers and people. The discussed research introduces very promising ideas for the exchange of machine understandable information stressing on the idea that computational entities in pervasive environments need to be context-aware so that they can adapt themselves to variations.

The basic standards discussed in all four papers include Resource Description Framework (RDF) and Web Ontology Language (OWL). This clearly signify the strength of the basics these two standards provide for defining the specification for data models and domain ontologies, respectively. The first paper introduces a propitious model for defining RDF rules, although the work focuses on prioritizing services and making intelligent recommendations for services but their actions and condition based rule structured served well in redefining of new model and ontologies to carry forward the context-awareness in pervasive computing.

The second paper in my opinion added new dimensions to the context-aware reasoning. It is like the use of polymorphism in reusing the parent class for defining general attributes and then specifying the details of these general concepts and features to a specific domain. This ontology structure laid grounds for practical reasoning models and domain specific ontologies for extracting high level context in complex environments.

Liao in [3]carried forward the works like the Forstadius's [1] RDF-based model and wang's[2] proposed CONON ontology to achieve safety in a smart home environment. The inclusion of time factor in the TempCRM model very effectively improves the risk calculations and predictions of any possible threats, since in a domestic environment potential risks are usually popped up by a particular object being at a particular location at or for a particular time. Moreover, a probability density function is a most suitable approach to model the chance factor of any potential risks in a smart home.

With all these ontologies and context reasoning rules in place there was a need for a familiar approach to dig into these ontologies so they can be implemented and used in more practical scenarios. The SOWL query language in [4] catered for this missing piece in the context aware reasoning. Furthermore, the contribution for the representation of dynamic information by ontologies is in fact a milestone in RDF and OWL based reasoning domain. All four research papers added reforms to the context-aware reasoning, but the optimum handling of information and reasoning is realized by SOWL, it sums up the existing works and incorporates spatio-temporal reasoning to infer underlying spatial and temporal information to relate the two objects. This model and the SOWL querying carry great potential for future extensions.

References

[1] J. Forstadius, O. Lassila, T. Seppanen and et.al, “RDF-based Model for Context-aware Reasoning in Rich Service Environment,” in *Third IEEE International Conference on Pervasive Computing and Communications Workshops*, Kauai Island, HI, USA, 2005.

[2] X. H. Wang, D. Q. Zhang, T. Gu and H. K. Pung, “Ontology Based Context Modeling and Reasoning using OWL,” in *Proceedings of the Second IEEE Annual Conference on Pervasive Computing and Communications Workshops*, Orlando, FL, USA, 2004.

[3] H.-C. Liao and C.-C. Tu, “A RDF and OWL-based temporal context reasoning model for smart home,” *Information Technology Journal,* vol. 6, no. 8, pp. 1130-1138, 2007.

[4] S. Batsakis and E. G. Petrakis, “SOWL:Spatio-temporal Representation, Reasoning and Querying over the Semantic Web,” in *Proceedings of the 6th International Conference on Semantic Systems*, Chania, Crete, Greece, 2010.