# Knowledge Management for Semantic Grid Enabled Integrated Wildfire Risk Assessment

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## Abstract

Wildfire is a major societal risk with complex behaviors. It can be defined as the probability that a particular place on the landscape will experience a wildfire, a highly flammable composition difficult to extinguish when ignited, within a discrete period and with predictable impacts on population and business. Wildfire risk has been related to a wide range of risk factors, such as fuel mass available, wind, temperature, and moisture as well as climate patterns, vegetation structure, terrain characteristics and human activities. In addition, wildfire risk may be considered at different spatial and temporal scales: from global to local, and from long term to short term. Risks at different scales are related to different risk factors with different risk assessment processes. There are a large number of existing heterogeneous data, models and other computational and analysis resources available to the wildfire risk management community. However, the challenge remains to intelligently discover, broker, compose and integrate these diverse existing and future resources to provide effective services for the wide variety of wildfire risk assessment and decision support needs.

In this paper, we present a knowledge management perspective of our on-going research based on use of emerging Semantic Grid technology. We first give an overall description of the proposed integrated wildfire risk assessment framework. We then focus on the knowledge management issues concerned with the way that knowledge is acquired and used within this framework.

## Keyword

Knowledge Management, Semantic Interoperability, Semantic Grid, Intelligent Information Access, Decision Support, Risk Assessment.

## Introduction

Wildfire is a major natural high-risk disaster in the United States. In 2002, for example, there were 88,458 fires that consumed nearly seven million acres with a fire suppression cost for that year estimated at 1.6 billion US dollars (NIFC 2002). In recent years, wildfires have become a significant management and science problem affecting our nation's ecosystems and wildland-urban interfaces. They also threaten human life and property and have significant ecological, social, and economic implications (Riebau and Qu 2004).

## Wildfire Risk Assessment Semantic Grid

One significant challenge is to give an integrated risk assessment based on a large variety of wildfire danger risk parameters derived from highly heterogeneous data sources: remote sensing, data from numerical weather prediction, ground measurement as well as human activity related socio-economic data. We will access the data based on available national data services.

NASA's Earth Observing System (EOS) missions have provided Direct Broadcast capability that can be used to generate real time fuel properties and fire danger potential risk indexes. Current MODIS (Moderate Resolution Imaging Spectroradiometer) VI (Vegetation Index) and LST (Land Surface Temperature) data can be obtained either from NASA DAACs or directly derived for MODIS DB measurements in HDF-EOS data format. GMU has a HRPT (High Resolution Picture Transmission) antenna for receiving data from AVHRR instruments on NOAA satellite series. About 10 scenes of data each day are downloaded directly to GMU/CEOSR facility and are available to all CEOSR personnel. The vegetation index values from AVHRR have a much longer history than those from MODIS.

In the wildfire risk assessment application domain, the centralized database with comprehensive wildfire risk related data does not exist and will be very difficult to implement in the future due to a wide variety of risk factors and highly heterogeneous data sources and associated services. Therefore, instead of creation of a central database for fire risk data, we propose to research and design a wildfire semantic grid to integrate heterogeneous data and services. It is foreseeable that this integration of distributed data and services will result in new value added information and derived knowledge for risk assessments. And this information and knowledge will be stored within the Semantic Grid.

In addition, we leverage current and future technology, DODS client software, SRB API, GIS and associated modules, etc. and integrate them by developing necessary software components. We will develop a wildfire risk assessment Semantic Grid to accommodate large volumes of dynamic heterogeneous risk data. In addition, this grid system will serve as a facilitator for data and information dissemination among the national wildfire risk management community.

The major components of the proposed grid include data service providers for specific data sources. For example, we plan to integrate our in-house NOAA AVHRR data downlink facility with data grid technology to have an instrument data grid node. Similarly, we may tailor grid nodes specifically for the USDA atmospheric model output data. This node may be implemented at a remote USDA computing facility. Other fire products and socio-economic data can be stored in another type of grid nodes.

In addition to the data service providers, there are risk modeling and analysis service providers. These service grid providers support the wildfire data analysis, risk modeling and risk assessment processes and in turn, the risk assessment processes will drive those services providers. This forms a fully integrated grid enabled risk assessment framework. For example, in the processes of data analyses and risk assessments, corresponding risk parameters linked to specific spatial and temporal scales will drive a variety of data grid services requests. The service broker will intelligently broke the requests to the corresponding data grid nodes that provide the requested data services. The processed data streams will be fed into our risk assessment data model and algorithms. The results will then be disseminated through grid enabled Web and GIS interface to fire managers, decision makers and disaster responders.

Knowledge management concerns itself with acquiring, accessing and maintaining knowledge within an application domain and it is a key challenge in building the wildfire risk assessment framework to enable efficient risk management decision support. The domain ontology represented through OWL (Web Ontology Language) allows explicitly captured formal conceptualizations (knowledge) of application domain models. Web Ontology Language (OWL) based on RDF (Resource Description Framework) meets the following requirements in knowledge representation: a well defined syntax, formal semantics, convenience of expression, efficient reasoning support and sufficient expressive power (Antoniou and Harmelen 2004).

In addition to the domain ontology, another important aspect of knowledge management is to enable intelligent service discovery, efficient service brokering and dynamic service composition based on the service request. Based on the specific risk assessment, and modeling operations performed, the grid service request can be produced accordingly. The service request will be sent and processed by the service broker. The service broker is responsible to discover, match and compose the right data and services provided within the Grid to serve the service request. Ontology based reasoning is the key in this service delivery process. For example, when a risk regression operation is performed based on a list of risk parameters (determined by its scale context and the risk knowledge base), a set of data service calls (against multiple data service providers) will be automatically generated by the service broker. The retrieved data will be integrated and ingested into the risk regression model. Finally, the regression results will be sent back to the service requester. The process of service discovery, brokering and composing and delivering is transparent to the risk modeling operations.

Semantic interoperability is the key to enable integration of existing and future distributed heterogeneous services in the application domain. The key enabling technology in this service-oriented architecture is OWL-S, which has three main components: the service profile for advertising and discovering services; the process model, which gives a detailed description of a service's operation; and the grounding, which provides details on how to interoperate with a service (OWL-S White Paper). With OWL-S markup of services, the knowledge necessary for service discovery could be specified as computer interpretable semantic markup, and a service broker or registry as well as ontology enhanced search engine could be used to locate the services matching with the service request. In addition, a service provider could proactively advertise itself in OWL-S with a service broker or a service registry so that requesters can find the services it provides.

## Conclusion

In this paper, we propose a Semantic Grid enabled wildfire risk assessment framework and our knowledge management approach for distributed heterogeneous resource integration and semantic interoperability. The proposed framework allows wildfire management decision makers to conduct scenario based risk analysis. The wildfire risk simulations can be carried out based on different user chosen risk situations such as weather conditions and fuel moisture conditions. Based on the probability of each risk situation, the overall risk mitigation measures may be derived and adjusted accordingly.

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