NSDI Cooperative Agreements Program Category 2: Best Practices in Geospatial Service Oriented Architecture (SOA)

Interim Report

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Agreement Number: 08HQAG0026

Project Title: Geospatial Service Oriented Architecture for Flood Inundation Mapping and Hazard Assessment

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Collaborating Organizations: Indiana Department of Homeland Security (IDHS), National Weather Service Central Region (NWS), the USGS Indiana Water Science Center, the Indiana University Community Grids Lab, and the Polis Center IUPUI.

Executive Summary

The primary objective of this project is to create a composite application using multiple web services to generate flood inundation geospatial grids and estimate flood-related property losses. Secondary outcome of this project is to document best practices in geospatial SOA.

Flood inundation grids are generated by using the U.S. Geological Survey's (USGS) Multi-Dimensional Surface-Water Modeling System (MD_SWMS) tool. This tool provides simulation programs for a variety of environmental and hydraulic models. One such hydraulic model that was used in this project is FastMECH. To achieve the objectives of the project, we developed an SOA Wrapper to the FastMech model, which allowed us to invoke FastMECH processes using SOAP APIs.

Property loss estimations are performed using a loss estimation calculation web service. This service overlays the flood inundation grids, generated from the FastMech model, with parcel level property data and calculates percentage damage to properties using Federal Insurance Agency (FIA) property damage curves.

Loss estimation calculation service uses two other data services—namely parcel centroids service and property assessment value service.

The overall flood inundation and loss estimation business process will be archived by using Business Process Execution Language (BPEL) technology to compose these web services.

We anticipate finishing and testing the services and the business process in the remaining months.

Project Narrative

Following is a list of project activities we performed.

- **Use case development:** We met with USGS, NWS, and IDHS stakeholders to elicit requirements and create use cases. We developed two use cases: 1) Response planning after NWS issues a flood watch or warning; 2) Development of mitigation strategies for "what if" scenarios for reducing the flood risk.
- **Web service development:** Following is a list of web services we developed.
  - **FastMECH flood inundation simulation web service:** Currently with this service we have the capability of providing a predefined CGNS file to simulate inundation and generate flood depth grids and velocity vectors. To generate predefined CGNS files, we use a standalone application. We are still working on a method for automating the creation of the CGNS file to simulate the model with variable model parameters in a process. We also will be developing methods to extract flood depth grid data and velocity vectors from CGNS files.
  - **Parcel centroids and property value data services:** We have developed these two support services for the Marion County geographic area in Indiana.
  - **Flood loss estimation and loss assessment web service:** This service overlays parcel point data on the flood depth grid file from FastMECH web service. It also selects the flooded parcels and calculates the percentage property damage using the FIA depth-damage functions. Depth-damage functions are plots of floodwater depth versus percent damage, plotted for a variety of building types and occupancies. The percentage property damage is then used with property assessment data to calculate the total losses to the property.
- **Business process development:** We composed these services using BPEL technology to model business processes for the two use cases.
- **Testing:** We have tested individual services and method APIs. We will be testing the complete workflows for the two use cases in the coming months.

SOA Definitions and Approach

The FastMECH application was written in FORTRAN programming language. Its SOA wrapper was developed under the Open Grid Computing Environments (OGCE) Job Submission Service framework using Java, which provides a set of Axis2 web services to execute and query status of the FastMECH application. FastMECH runs on computing resources managed by Condor system.

The rest of the web services were developed in vb.net and compiled against Microsoft CLR 3.5. These web services will be deployed under Internet Information Server (IIS) 6.0.

For BPEL modeling, we used Sun's Netbeans application. The BPEL application will be deployed under Sun GlassFish Enterprise Server v3.

Requirements and Process Definition

To elicit requirements, we met with meteorologists, hydrologists, and mitigation planners. After these meetings, we developed use cases and process flows of the project. The following sections describe the use cases and data inputs and outputs.

Usage Scenario:

Composition of a Geospatial Service Oriented Architecture for Flood Inundation Mapping and Hazard Assessment

Authors:

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- **John Buechler, The Polis Center, IUPUI**
- **Marlon Pierce, Community Grids Lab, Indiana University**
- **Sally Pavlow, National Weather Service**
- **Scott Morlock, USGS Indiana Water Science Center**
- **Moon Kim, USGS Indiana Water Science Center**

Domain: Hydrology, Geospatial SOA, Flood Hazard Damage Assessment, GIS Visualization, Near Real Time Flood Inundation

Description

The National Weather Service (NWS) and the U.S. Geological Survey work closely with state agencies—for example, the Indiana State Emergency Management Agency (Indiana Department of Homeland Security, IDHS)—when natural hazards such as severe storms and flooding occur. The State Emergency Operations Centers are manned twenty-four hours a day by staff from a variety of state agencies during these events. The most frequent severe weather-related disasters involve riverine flooding. The NWS provides flood warnings and forecasts before and during flood disasters. The USGS provides flood information to the NWS for its use in flood warnings and forecasts; the information is provided in near real time from a network of stream gages. Stream gages provide water level (stage) data and volumetric streamflow data. IDHS coordinates emergency response and recovery activities using the best available information from the NWS and USGS on the extent of the flooding. The severe June 2008 floods starkly illustrated this risk and the necessity for interagency collaboration.

The Federal Emergency Management Agency (FEMA) supports the activities of the Indiana Department of Homeland Security (IDHS) and local governments that can prevent or reduce the significant losses resulting from disasters. Recognizing that flooding is the most widespread and significant natural hazard in Indiana, and that major flooding occurs within Indiana almost every year, IDHS sees a critical need to assess the potential severity and extent of floods in the update of hazard mitigation plan risk assessments. The updated risk assessments will be used to improve the mitigation strategies for communities.

Issues

- Tools do not readily exist to visualize the projected extent and depth of the flooding or estimate the damage to the affected structures in near real time.
- Web tools for disseminating information between agencies and to the general public need to be improved.
- There currently is limited ability to run extensive validation scenarios of the models using historical data.
- Flood forecasts need to be automated and event-driven using open Web architectures.

Actors & Goals

- Meteorologists, The National Weather Service (NWS)
- Hydrologists, The National Weather Service (NWS)
- Hydrologists, The U.S. Geological Survey, (USGS)
- Hydrologists, The Indiana Department of Natural Resources, (IDNR)
- Hydrologists, The Army Corps of Engineers (USACE)
- Hazard Analysts, Federal Emergency Management Agency (FEMA)
- Hazard Analysts, Indiana Department of Homeland Security, (IDHS)
- Hazard Analysts, Indiana Department of Natural Resources, (IDNR)
- Environmentalists, Environmental Protection Agency (EPA)
- FastMech Simulation service
- Assessment Data Service
- Parcel Data Service
- Loss Estimation Service
- Web Map Service
- GeoRSS and KML forecast streams

The goal is to develop an SOA base composite application to assist the following:

- Hazard response planning
- Developing mitigation strategies for "what if" scenarios for reducing the flood risk

Stakeholders & Interests

The Indiana Department of Homeland Security (IDHS) is responsible for supporting activities that can prevent or reduce the significant losses that result from disasters. Recognizing that flooding is the most widespread and significant natural hazard in Indiana, IDHS sees a critical need to apply computer-based geospatial, hydrologic, and river hydraulic flood modeling tools with HAZUS-MH risk analysis software for the purpose of assessing the frequency and severity of floods.

This project leverages resources from a variety of agencies including IDHS, the Indiana Department of Natural Resources (IDNR), the USGS, The Polis Center, the National Weather Service (NWS), and the U.S. Army Corps of Engineers (USACE). Flood Mitigation is a focus activity of the Indiana Silver Jackets, an inter-agency natural hazard mitigation team. Using the technology to expand mitigation efforts highlights the collaboration of the Silver Jackets member agencies (FEMA, USACE, USGS, NWS, IDHS, IDNR, Department of Housing and Urban Development, and U.S. Department of Agriculture Natural Resources Conservation Service).

Within the last year, new computer resources with the potential to substantially improve the accuracy of flood risk assessments have become available, including high-resolution digital ground elevation models equivalent to contour intervals of one or two feet; and an update to FEMA's HAZUS-MH risk assessment and hazard mitigation planning software program that allows users to easily import a flood surface to perform loss estimates, detailed digital local building inventory data, and state-of-the-art river flood hydraulic programs developed by the U.S. Geological Survey (USGS). These new computer resources, in combination with other new hazard science information, would produce detailed estimates of flood damages

URL(s) or Other References

Modification History

- Neil Devadasan, June 09, 2008
- John Buechler, Neil Devadasan, June 16, 2008
- Marlon Pierce, June 16, 2008
- John Buechler, Neil Devadasan, July 8, 2008

Use Case: Response planning after NWS issues a flood watch or warning

Issues

IDHS is concerned about flooding.

Requirements

No specific requirements.

Actors/Roles

- *Available Services:*
    1. FastMech Simulation:
        - Input: DEM, USGS real time stream gage data, NWS five-day flood forecast data
        - Output: Flood depth GRID ASCII file
        - Preconditions: Calibration of the surface model
        - Effects: Event Raised => flood_depth_grid_generated
    2. Parcel Data Service:
        - Input: Flood depth GRID ASCII file
        - Output: Parcel information
        - Preconditions: True
        - Effects: Event Raised => parcel_information_for_grid_generated
    3. Assessment Data Service:
        - Input: Parcel information for the grid
        - Output: Property assessment information
        - Effects: Event Raised => property_assessment_information_generated
    4. Loss Estimation Service:
        - Input: Property assessment information, HAZUS-MH damage curves
        - Output: Parcel information
        - Preconditions: HAZUS-MH damage curves calibration
        - Effects: Event Raised => damage_estimations_generated
    5. Web Map E-Service:
        - Input: Property assessment information, parcel centroids, GRID file
        - Output: Map of flood inundation and affected parcel centroids and affected parcel information with an Arial photo background.
        - Additional output: KML and GeoRSS feeds of output.

  - Effects: Queriable web site with maps and tables

- *End-users and their roles*:
  1. Meteorologists
     - Meteorologists model weather events which provide input data to develop stream flow estimates.
  2. Hydrologists
     - Hydrologists generate flood forecast information and also capture real time streamgage data. Then hydrologists perform the inundation modeling.
  3. Hazard Analysts
     - Hazard analysts use the output of the model to determine the extent and severity of flooding.
  4. Environmentalists
     - Environmentalists use the output of the model to determine potential environmental impacts of the flooding, including hazardous materials locations within the flooded area.
  5. General Public
     - The general public checks web sites for latest flood forecasting results.

Assumptions

We assume the following:

- Web-accessible data sources such as stream gages will be reliable (i.e. provide accurate and timely data) and robust.

- The flood modeling codes give reliable forecasts (has been validated).

- The workflow described above can be executed in a timely fashion.

Scenario/Steps

1. NWS issues a flood watch or warning; IDHS is concerned about flooding.
2. Based upon USGS streamflow-gaging station data, or NWS flood prediction data, an approximate two-year (50 percent) flood is reached.
3. USGS FastMECH flood inundation web service is automatically activated.
4. Upon receiving flood_depth_grid, parcel data service is activated.
5. Upon receiving parcel_information_for_grid_generated, assessment data service is activated.
6. Upon receiving property_assessment_information_generated, loss estimation service is activated.
7. Upon receiving damage_estimations_generated, maps are generated by web map e-service and published for analyzing.

Reasoning Techniques Required

- Advance planning techniques
- Data integration techniques
- Error detection and validation of results (i.e. avoid or minimize human errors that may result in incorrect forecasts).

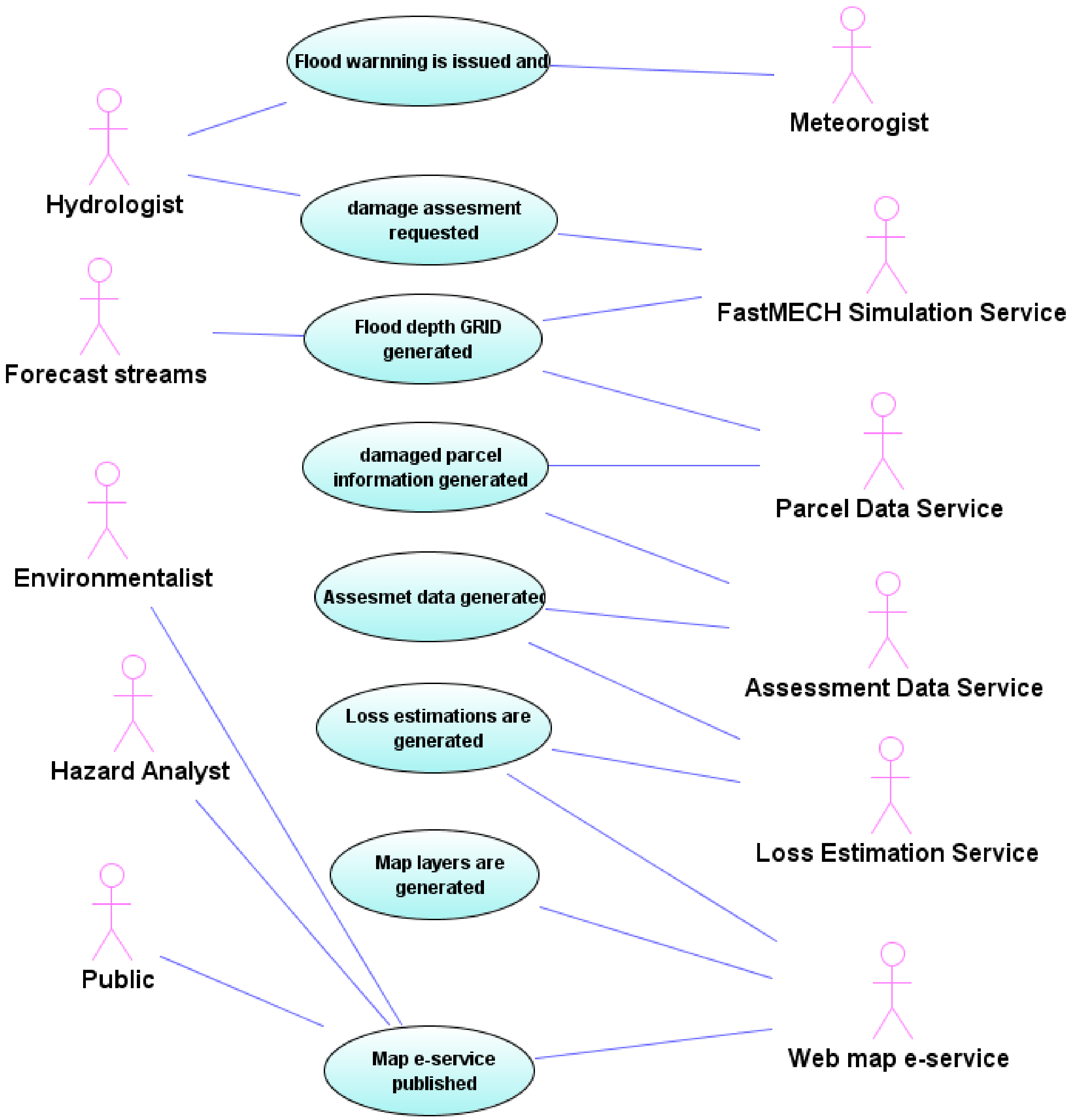

Figure1: UML Use case diagram

Use Case: Developing mitigation strategies for “what if” scenarios for reducing the flood risk.

Issues

FEMA, IDHS, and the local community would like to assess flood risk for several flood frequencies and then develop mitigation strategies. As part of this effort, the community would develop an annualized estimate of flood risk.

Requirements

No specific requirements.

Actors/Roles

- *Available Services:*
    1. FastMech Simulation:
        - Input: DEM, User-supplied discharges for specific gauge locations
        - Output: Flood depth GRID ASCII file
        - Preconditions: Calibration of the surface model
        - Effects: Event Raised => flood_depth_grid_generated
    2. Parcel Data Service:
        - Input: Flood depth GRID ASCII file
        - Output: Parcel information
        - Preconditions: True
        - Effects: Event Raised => parcel_information_for_grid_generated
    3. Assessment Data Service:
        - Input: Parcel information for the grid
        - Output: Property assessment information
        - Effects: Event Raised => property_assessment_information_generated
    4. Loss Estimation Service:
        - Input: Property assessment information, HAZUS-MH damage curves
        - Output: Parcel information
        - Preconditions: HAZUS-MH damage curves calibration
        - Effects: Event Raised => damage_estimations_generated
    5. Web Map E-Service:
        - Input: Property assessment information, parcel centroids, GRID file
        - Output: Map of flood inundation and affected parcel centroids and affected parcel information with a Ariel photo background
        - Effects: Queriable web site with maps and tables
- *End-users and their roles*:
    1. Meteorologists
        - None
    2. Hydrologists
        - The hydrologists provide discharge data for each theoretical flooding event.
    3. Hazard Analysts
        - The hazard analysts use the output of the model to analyze the risk from each flood scenario.
    4. Environmentalists
        - The environmentalists use the output of the model to determine potential environmental risks from each flood scenario.
    5. Local Community
        - The local community desires to prepare a detailed flood risk assessment.

Goals/Context

Assumptions

1. Accurate historical data (both inputs and outputs) are available.
2. Estimated losses from accurate sources.

Scenario/Steps

1. The local community working with IDHS desires to prepare a detailed flood risk assessment.
2. The local community provides flood scenarios to the IDHS, USGS, and/or other partner agencies
3. USGS provides historical streamflow and flood frequency data.
4. USGS FastMECH flood inundation web service is activated.
5. Upon receiving flood_depth_grid_generated, parcel data service is activated.
6. Upon receiving parcel_information_for_grid_generated, assessment data service is activated.
7. Upon receiving property_assessment_information_generated, loss estimation service is activated.
8. Upon receiving damage_estimations_generated, maps are generated by web map e-service and published for analyzing.
9. IDHS and local community analyze the data, if necessary change the flood discharges and reiterate simulation.

Reasoning Techniques Required

- Advance planning techniques
- Data integration techniques

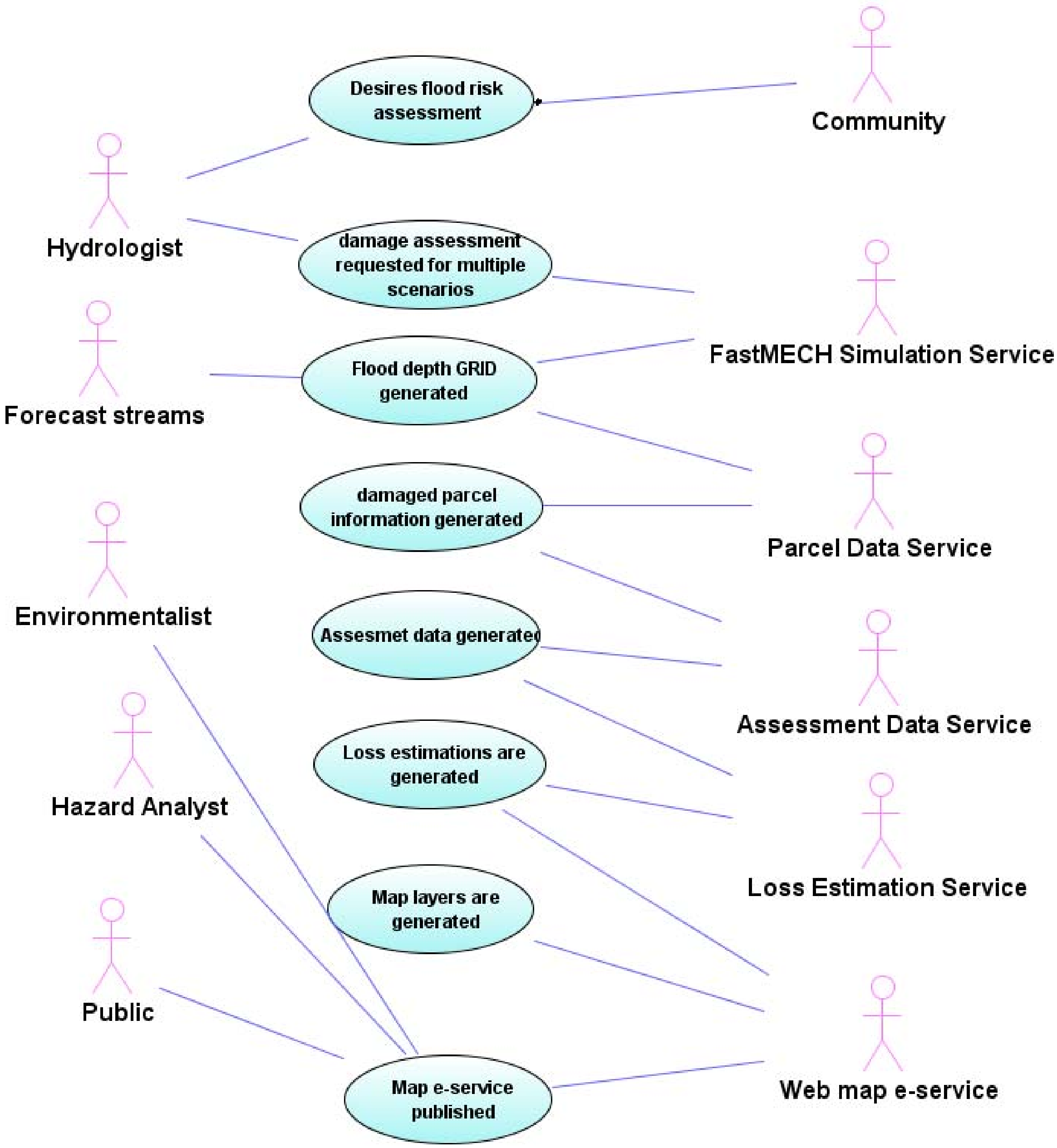

Figure2: UML Use case diagram