16TH EUROPEAN CONFERENCE ON
EARTHQUAKE ENGINEERING
THESSALONIKI
18 - 21 JUNE 2018

ERGO: OPEN SOURCE PLATFORM FOR MULTI-HAZARD ASSESSMENT, RESPONSE AND PLANNING

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ABSTRACT

Ergo is an open source multi-hazard assessment, response, and planning platform that is supported by the Ergo consortium of users and developers lead by the National Center for Supercomputing Applications (NCSA). The Ergo platform is a spatially enabled, extensible, semantically-aware Java plug-in based platform based on the Eclipse Rich Client platform (RCP) that allows developers to extend the platform and add new functionality, data types, visualizations, analyses, etc. to enrich the platform capabilities. Ergo provides support for multiple hazards including Earthquake and Tsunami with the ability to extend the platform to other hazards, inventories, etc. through Eclipse extension points that allow developers to plug in new capabilities. Ergo has a core set of 50+ analyses that span assessing built-in infrastructure such as buildings, bridges, pipelines, etc. for physical damage to socio-economic analyses to assess the impact of displaced population (population dislocation) and short term shelter needs. Ergo users can extend the platform by providing new data (fragilities, functionality, etc.) so the platform uses the state of the art input data when assessing their infrastructure and Ergo developers can extend the platform by providing new analytical capabilities representing the state of the art science and engineering understanding so Ergo remains at the forefront of multi-hazard assessment, response and planning.

In addition to the work done by the consortium, Ergo has several active communities extending the platform to meet their specific needs including IN-CORE for the Center for Risk-Based Community Resilience Planning (USA), CaribeViz for seismic risk assessment application for Caribbean states, Ergo-CRC for the Convergence Research Center for Disaster-Hazard Resilience (S. Korea), software development for Eu-CIRCLE, and Dr. Nisrine Makhoul of the University of Balamand, Lebanon, who has been using Ergo to study Byblos building and buried pipelines. This paper will share the Ergo platform with use cases and recent activities around Ergo platform.

Keywords: Risk Assessment, Open Source Platform, Multi-Hazard

1 INTRODUCTION

Natural and man-made hazards can happen to any region of the world with lasting effects felt on a global scale. State of the art software tools are required that can help understand the impacts of these disasters and help with loss assessment, response and planning to mitigate the consequences of these events. The Ergo Consortium has been developing and actively maintaining Ergo, a state of the art open-source software platform for multi-hazard loss assessment, response and planning to help mitigate hazard events, for nearly 15 years. Ergo was originally based on the MAEViz software developed for the Mid-America Earthquake (MAE) Center as a joint effort between the MAE Center and NCSA (Myers, Spencer and Navarro 2006). The project began in 2002 as a tool to visualize earthquake damage; however, not long after the initial prototype, requirements emerged to build

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analytical capabilities into the software that could be connected with the visualization pipeline so models could be applied and results seen in near real time. Incremental features and design changes continued until 2009. Even after project funding ended, the international user community continued to grow. NCSA continued performing minor software maintenance until November 2012 when NCSA and international partners launched Ergo open source consortium as a sustainable software model. The Ergo consortium consists of international partners from more than 9 countries and has held 3 annual workshops. The first annual workshop was held in Vienna, Austria from September 14 through September 16, 2013. The second annual workshop was held in Istanbul, Turkey on August 24, 2014. The third annual workshop was held in Athens, Greece from October 5 through October 7, 2015. Ergo was reviewed by the World Bank in 2014 among 80 open source software systems. Their assessment stated, “It is easily the best software for scenario risk assessment and decision support (mitigation, benefit-cost)” (World Bank 2014, p.18).

Ergo was designed to be an extensible risk assessment platform, made available to both scientific researchers and community decision-makers. Although it was initially developed to specifically support seismic risk assessment, the extensibility of the architecture has allowed Ergo to broaden its focus to other hazards, both by the Ergo consortium as well as by external groups who have branched from the Ergo source. The platform has been extended over the years to apply to many different natural hazards as well as the socio-economic impacts of these disasters. Primarily developed at National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana Champaign, Ergo has been adopted and used by many different research institutions throughout the world. Because Ergo is made available under an open source license, researchers from many different institutions and organizations can both contribute and use the code base to aid them in their investigations. New scientific analyses, data, and functionality can be added to the core platform as additional research is done, which allows Ergo to quickly be adapted to new regions and scientific methodologies.

In this paper, Section 2 provides a high-level introduction to the Ergo architecture. Section 3 introduces new features of the latest Ergo platform. Section 4 shows activities around Ergo community. Section 5 provides a summary of the paper.

2 ARCHITECTURE

The core technologies of the Ergo platform include Eclipse Rich Client Platform (RCP), Geotools, Visualization Toolkit, JFreeChart, KTable and Jasper reports. These technologies make up the core of Ergo and provide capabilities such as data management, visualization, analysis, etc. as shown in Figure 1. The Ergo platform is an extensible system, a semantically-aware system, and a geospatial system.

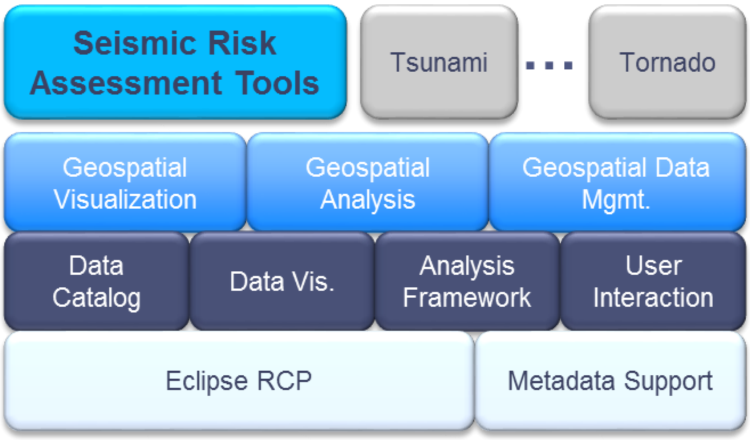

Figure 1. Ergo architecture

2.1 *Extensible System*

The Eclipse RCP framework allows Ergo to be extensible via the Open Services Gateway Initiative (OSGi) specification, which describes a modular system and a service platform for the Java programming language that allows applications to be extended by adding new bundles that add or extend capabilities of the platform. Eclipse builds on this through the concept of extensions to contribute functionality to a certain type of application programming interface (API) defined by a plug-in through an extension point. A plug-in defines a contract or API with the definition of an extension point. This allows other plug-ins (bundles) to add contributions (extensions) to the extension point. Extension points allow developers to identify parts of an application that others might want to extend to add new capabilities.

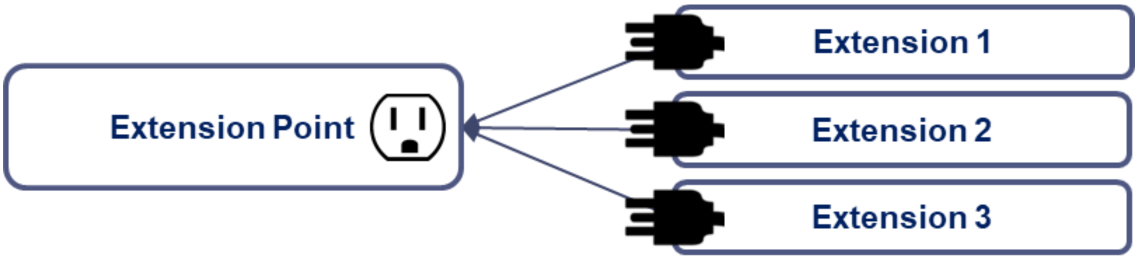

Figure 2. Eclipse RCP plug-in architecture

Ergo has several such extension points that allow developers to add new data types, new visualizations, new user interface components, new analyses, new attenuation models, etc. For example, a building inventory data type is an extension to *data type* extension point. A plug-in contains the new data type that extends the extension point, it will be recognized by Eclipse RCP automatically when the application starts.

2.2 *Semantically-aware System*

Ergo includes many defined data types including bridges, buildings, etc. New data types can be added through the *gisSchema* extension point. Defining a new data type through the extension point allows Ergo to collect information about the data such as the types of information contained within the dataset (e.g. number of stories, bridge spans, etc.). This information allows developers to specify a default style for each data type as well as analysis chaining. In other words, the Ergo platform knows the type of each data set (e.g. building inventory) and knows what to do with the identified data type.

For example, if an analysis defines that it requires building damage in the analysis description, Ergo knows which analyses can produce building damage and can be chained to provide the input. As shown in Figure 3, four analyses are chained together according to their input/output data types. In addition, Ergo's search button for each analysis input uses the defined data types to search for data by type so when users search for bridges, only bridge data results are returned.

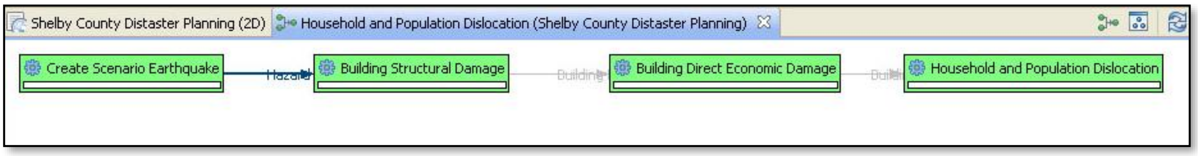

Figure 3. Ergo analyses chained by data types

2.3 Geospatial System

The geospatial capabilities in the Ergo framework come from Geotools[4], an open source Java GIS toolkit, that provides the ability to read and write ESRI shapefiles, ESRI ASCII grid files, etc. The library is also OGC[5] specification compliant (e.g. simple feature specification[6], etc.). By using Geotools, Ergo platform follows OGC specification inherently. For example, the style of a layer is defined in SLD (Styled Layer Descriptor) specification[7]. The geospatial data type, which contains the georeferenced geometries, are defined with GML (Geography Markup Language) 1.0 specification[8].

Ergo provides two types of mapping visualization: 2D and 3D. 2D visualization allows users to overlay various geospatial layers to create a desired map. From Ergo's Scenario view, users can have control of the layer's visualization, such as changing order of layers, changing styles, and changing visibility. For 3D visualization, users can choose which variables (fields) from the data be used in the visualization. The 3D visualization will show different shapes according to the geometry type of the data (e.g. pipe for line geometry) as shown in Figure 4.

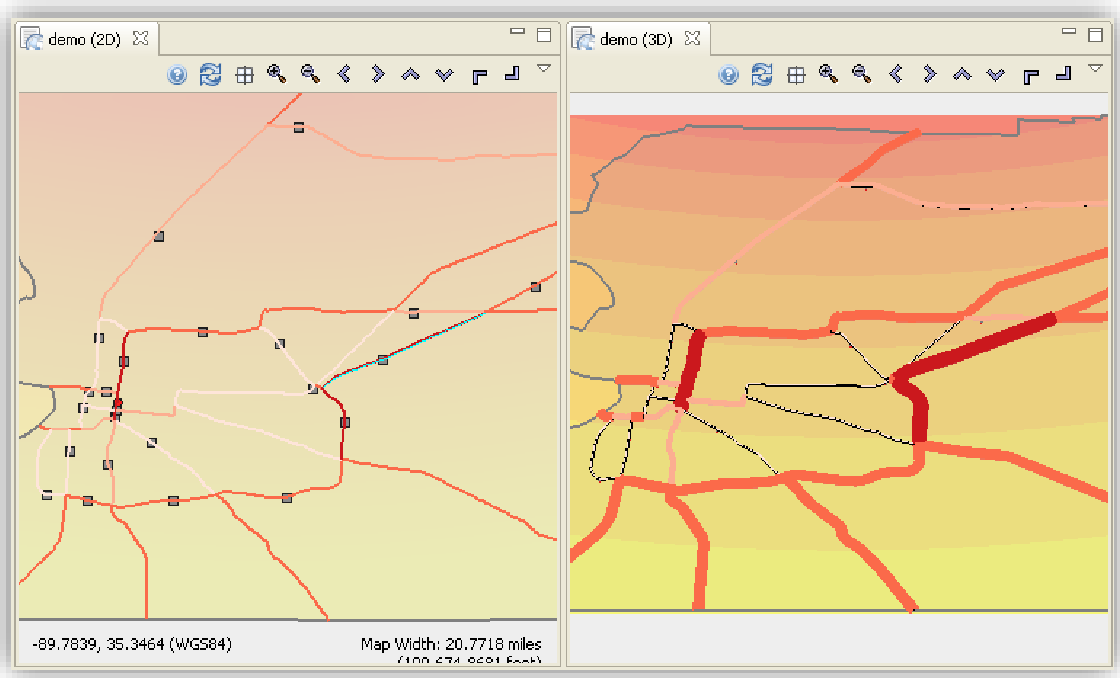

Figure 4. 2D map and 3D map in Ergo showing highway traffic

2.4 Analysis Framework

Ergo currently includes a number of scientific analyses and can be extended to add new analyses as they are needed. At this time, Ergo supports running a chain of analyses to create an earthquake hazard, apply it to a set of inventory data to determine structural and non-structural damage, and then use these results as inputs to various socio-economic and decision support analyses. Many different types of inventory data are supported, such as bridges, buildings, electric power networks, and buried pipelines. Using the collection of these various analyses, scientists and decision makers can focus on a

[4] http://geotools.org/
[5] http://www.opengeospatial.org/
[6] http://www.opengeospatial.org/standards/sfa
[7] http://www.opengeospatial.org/standards/sld
[8] http://www.opengeospatial.org/standards/gml

specific area of risk in a community. The Figure 5 shows analyses on Ergo in different categories and dependencies between analyses.

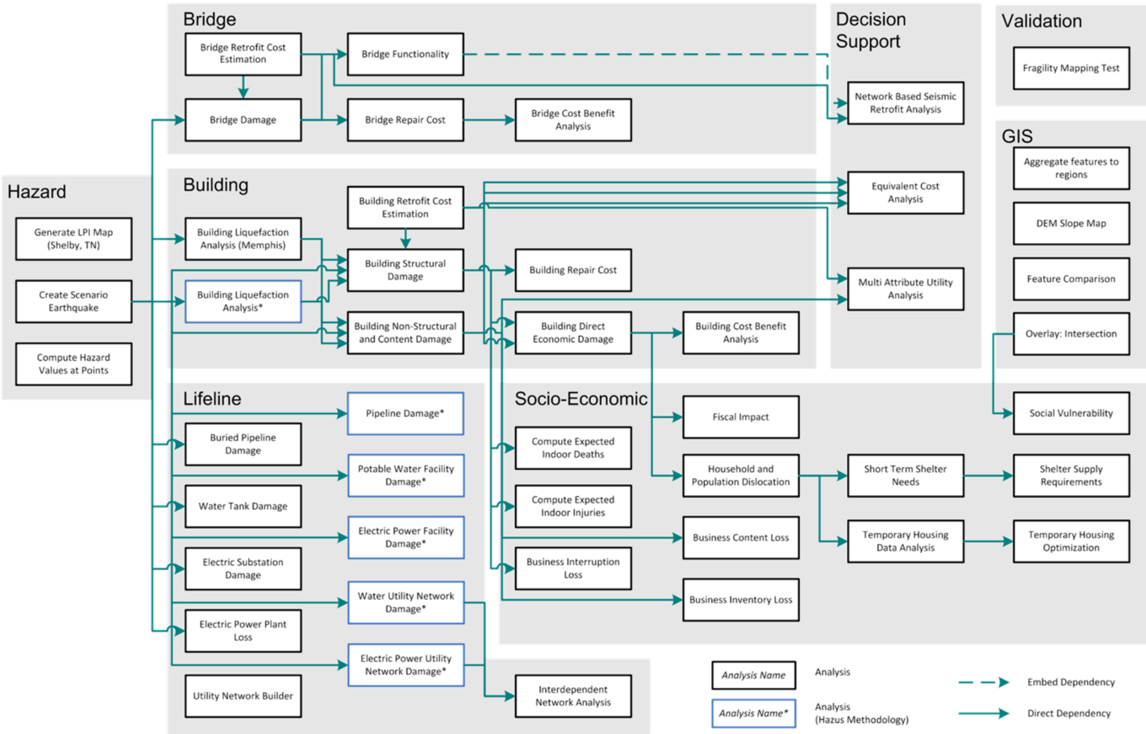

Figure 5. Analyses on Ergo

Because the Ergo analysis framework is specifically designed to allow analyses to be chained together (so that the output of one analysis can be used at the input for another), creation of a new analysis only requires adding code that supports the new computation done by that analysis. This allows the developer of a new analysis to more quickly create, for example, new socio-economic research that depends on the results of building damage, as they are able to reuse the existing building damage analysis as input to their new analysis.

The extensible nature of Ergo's plugin-based architecture allows for these new analyses to be added without having to rebuild the entire Ergo platform, allowing rapid enhancement by any user of Ergo. Each Ergo Analysis is defined by two parts: an xml-based description file, and java code that performs the actual computation of the analysis. The description file allows the analysis author to declaratively express many of the details specific to that analysis. For example, the analysis author will describe the various inputs to an analysis, including the data type of each input. The Ergo GUI (Graphic User Interface) will then automatically generate a user interface for allowing the end-user to select appropriate data for each input as shown in Figure 6.

The enumeration of input and output data types in the analysis description file allows the system to also dynamically chain together analyses, so that the output data of one analysis becomes an input to the next analysis. For example, the result of a "Create Earthquake Hazard" analysis can be set as the input of a "Building Structural Damage" analysis, which then generates a dataset of structural damage. This resulting dataset can then again be applied as input to an analysis that computes economic damage from structural damage. This integration and chaining of analyses allows Ergo to do computation across an entire suite of analyses, beyond what each individual analysis would support alone.

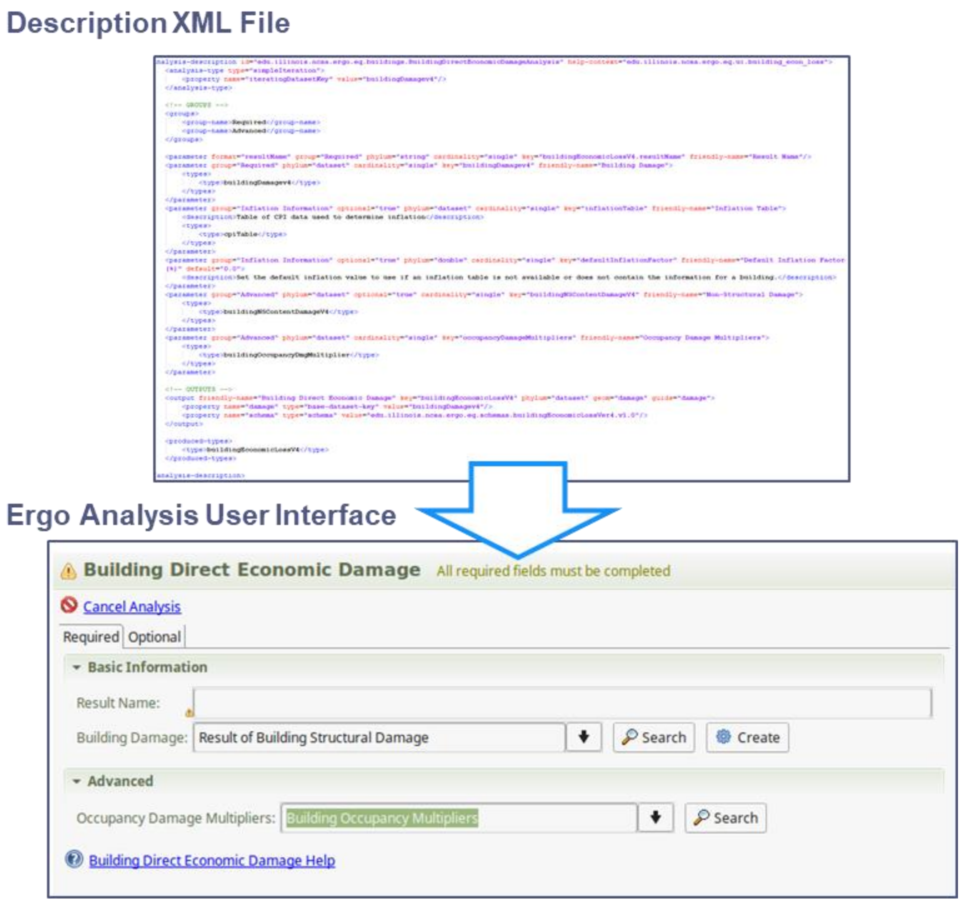

Figure 6. Ergo analysis framework: description xml file to GUI

3 NEW FEATURES

This section introduces two new features of the Ergo platform, which allow users to more easily create their own analyses, and support for developing High Performance Computing (HPC)-based analayses.

3.1 DataWolf Support

Ergo now includes support for running scientific workflows using DataWolf, an open source scientific workflow engine developed at NCSA. DataWolf can be called by other applications using DataWolf's REST API. As shown in Figure 7, a new preference page was added that lets users specify the machine where DataWolf is running (in this case https://datawolf-dev.ncsa.illinois.edu:8888/datawolf) and the username and password of the account to execute jobs.

This addition of DataWolf allows developers to add new analyses to Ergo written in other languages and/or requiring more computational resources than the machine running the Ergo Desktop application. To simplify the process of adding new DataWolf analyses, a new DataWolfBaseTask class was created that contains the common functionality required for the new analyses such as authenticating the user using the information provided in the preference page, uploading and downloading datasets, executing the workflow, and getting the workflow status for the developer. Developers can extend this class and add only their analysis specific code for executing the new analysis. To illustrate the new DataWolf capabilities in Ergo, an example plugin was created, edu.illinois.ncsa.datawolf.example, that calls a DataWolf workflow for computing building damage using a python script. Similar to other Ergo analyses, Ergo provides the user interface for setting up the analysis for execution; however, instead of executing the analysis on the users local machine, the analysis execution happens on the remote DataWolf server. When the analysis is complete, Ergo will retrieve the results to the users local cache and visualize the result dataset.

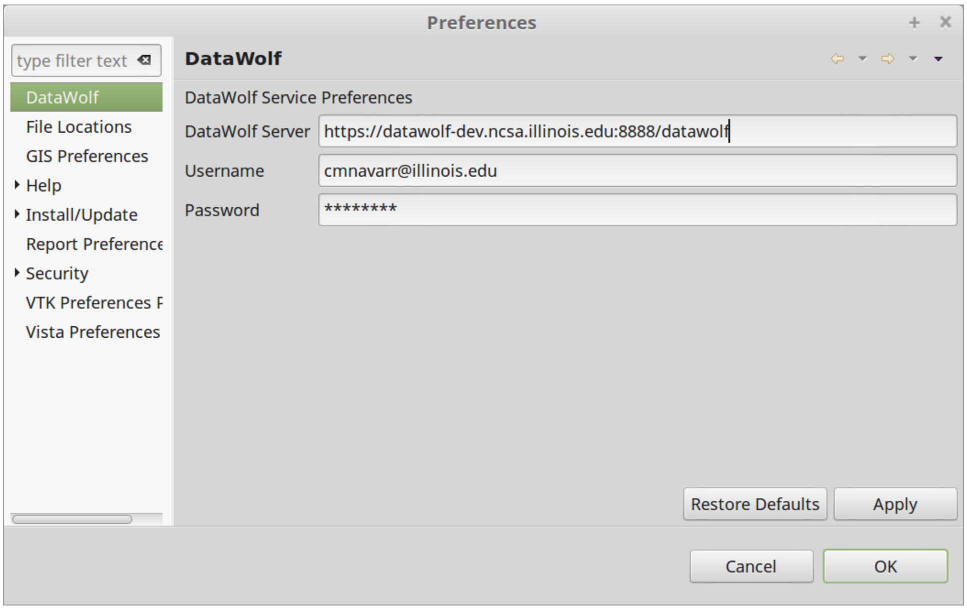

Figure 7. DataWolf preference page

3.2 HPC Support

In addition to executing jobs on the local machine, Ergo has support for executing jobs on high performance computers (HPC) using DataWolf's HPCExecutor. In the previous section, the example was running on the machine where DataWolf is installed; however, DataWolf can also launch HPC jobs using the HPCExecutor. The HPCExecutor is configured to handle staging data to the HPC, checking job status, and retrieving results using the Secure Shell (SSH) protocol. See Figure 8 below:

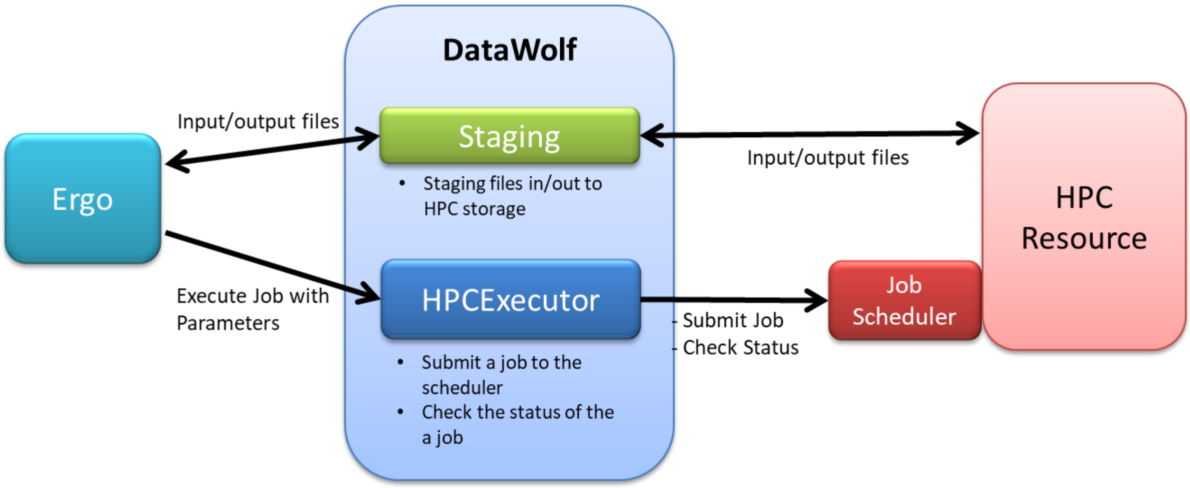

Figure 8. Architectural design for HPC support on Ergo

Similar to the previous section, Ergo can be configured to access a specific DataWolf instance and communicate with it using DataWolf's REST API to run workflows and retrieve results once the workflow execution is finished. From the Ergo user perspective, Ergo is agnostic of where DataWolf is running the job (e.g. local DataWolf execution looks no different than DataWolf HPC execution) since all the communication between Ergo and DataWolf happen through the REST API. Coupled with the work from the previous section, this will allow any executable that is compiled for an HPC resource to be made available to Ergo and executed via DataWolf.

4 ACTIVITIES

Ergo has been extended by several communities to meet their specific needs by creating community specific branches of the Ergo Platform through a process called forking. This creates a branch of the code that is separate from the main development branch. These forks include HazTurk, a fork of Ergo for Turkey (Elnashai et al. 2003), EqVis[9] for SYNER-G, the European Union, CaribeViz for seismic risk assessment application for Caribbean states, Ergo-CRC for the Convergence Research Center for Disaster-Hazard Resilience, S. Korea, and EU-CIRCLE is adding new functionality to a fork.

Figure 9. Forks of Ergo

In addition to these forks, there are collaborative projects that use Ergo as a base platform to build new functionality/software. The primary difference is that collaborative projects build their software against Ergo so any changes to Ergo are included in their software as well including new features, bug fixes, improvements, etc. The IN-CORE[10] project for the Center for Risk-Based Community Resilience Planning (USA)[11] is adding new hazards, fragilities, analyses, etc. to the standard set of analyses in Ergo. Similarly, a project with Multi-Disaster Countermeasures Organization, S. Korea, titled the Risk assessment for high-rise and mixed-use buildings, is building upon Ergo and adding new attenuations to the existing set as well as working on new DataWolf analyses to assess high-rise and mixed-use buildings using HPC.

The Ergo consortium also works with researchers to assist them in running Ergo analyses with their data. For example, the Ergo team has worked closely with Dr. Nisrine Makhoul of the University of Balamand, Lebanon, who has been using Ergo to study Byblos building and buried pipelines (Makhoul et al. 2016). Another example is with Joshua Macabuag of University College London. The consortium helped get tsunami fragilities and tsunami inundation data into Ergo to compute building damage from a tsunami.

5 CONCLUSION

Natural and man-made hazards will continue to affect the world on a global scale; however, tools such as Ergo can help communities understand the potential impacts of these disasters through state of the art loss assessment tools that can help communities with response and planning to mitigate the consequences from these events. The extensibility of the platform lends itself to be adapted to meet the needs to different communities by allowing researchers to add the latest research and data so Ergo has the most complete and advanced loss assessment capabilities to aid in response and planning for all hazard events.

[9] http://www.vce.at/SYNER-G/files/downloads.html
[10] http://resilience.colostate.edu/in_core.shtml
[11] http://resilience.colostate.edu/index.shtml

The Ergo Consortium along with their international partners, will continue to update and extend the platform with bug fixes and improvements, new rendering capabilities to support public mapping services like OpenStreetMap, complete the extension to HPC, and support the Ergo community and external researchers to help them add new analytical capabilities and data so the platform continues to be the state of the art for multi-hazard assessment, response and planning.

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