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Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	x
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

```
 */
public class GemComputeHazard implements Runnable {

    private class computeHazardRange{
        public int start, end;
    }

    // hazard curve repository
    private GEMHazardCurveRepository hcRep;

    // list of sites where to compute hazard curves
    public ArrayList<Site> siteList;

    // earthquake rupture forecast
    public EqkRupForecast ERF;

    // input sources
    ArrayList<GEMSourceData> sourceList;

    // attenuation relationship vs. tectonic region map
    public HashMap<TectonicRegionType,ScalarIntensityMeasureRelationshipAPI> gmpeMap;

    // intensity measure level list
    private ArbitrarilyDiscretizedFunc imlList;
```

ABSTRACT

This document describes the structure and the main characteristics of the Seismic Hazard Engine (SHE) primarily developed in cooperation by the hazard team of the Global Earthquake Model (GEM, www.globalearthquakemodel.org) initiative and, by members of the USGS hazard team. The SHARE team cooperated to the development of the engine by providing input models together with extensive insights and suggestions with specific regard to the European context as specified in the following part of this document. The SHE, created on top of OpenSHA (www.opensha.org) and fully integrated with it, accepts a set of standardized source typologies characterized by a time-independent occurrence model. Through the SHARE-GEM cooperation we ensure full compatibility with the developments to assess risk on a Euro-Mediterranean scale through the risk assessment engine of GEM.

The SHE calculates hazard following the procedure proposed by Field et al. (2003). It accepts PSHA input models accounting for epistemic uncertainties in the definition of the Earthquake Rupture Forecast (ERF, in some cases also called the seismicity occurrence model) and epistemic uncertainties related to the definition of the Intensity Measure Relationships (IMR) more widely known as Ground Motion Prediction Equations (GMPEs).

The engine can generate a set of stochastic event sets representative of a given time span (just by sampling an ERF) and associate to each generated event a scenario shake map, with the possibility of accounting for the spatial correlation of ground motion. This feature will be of particular interest for future risk applications.

The current version of the engine was successfully tested using diverse PSHA input models in the GEM1-pilot project phase, including the computation of a re-engineered European-Mediterranean model, a derivative of the outcomes from the SESAME-project. In the present version this document focuses on the description of the standard procedure adopted for hazard calculation.

Up front, we would like to thank: Ned Field (USGS) and his team for support, the code base and continued efforts to improve OpenSHA.

Keywords: Probabilistic Seismic Hazard Assessment (PSHA); OpenSHA

1 Introduction

The development of a flexible and robust computational engine for probabilistic seismic hazard assessment (PSHA) is a major requirement in SHARE and an essential milestone for the entire project. According to the SHARE Document of Work, the computational engine shall satisfy the following general requirements:

- Compute seismic hazard using the classical PSHA approach;
- Compute synthetic seismicity histories (or stochastic event sets) and scenario shake maps;
- Provide the flexibility to deal with all complexities of PSHA input models required for a harmonized seismic hazard assessment on a Euro-Mediterranean scale;
- Being included in an infrastructure that remains active beyond the completion of SHARE and serves as a regional center within the framework of the Global Earthquake Model (GEM). Within the GEM initiative, SHARE shall contribute to raise global standards in PSHA.

Due to the close integration of SHARE as a regional component of the GEM initiative, we profited from synergies in the development of the computational platform. Through this process, we ensure that specific requirements of SHARE are met. These detailed requirements for the computational engine are:

- Calculate seismic hazard maps, scenario shake maps, site-specific hazard curves, site specific hazard spectra and disaggregation of seismic hazard outputs;
- Be adaptable to future hazard models and outputs;
- Calculate results necessary for use in risk assessment

The OpenSHA framework, a free object-oriented open-source software framework [Field et al., 2003] forms the base of the seismic SHE (SHE). The software is designed to handle diverse data sources and multiple model types in a modular framework. It has proven to be extensible during for the current needs of the SHARE project and ideally suited for further development through its software philosophy.

For the development of the SHE, two fundamental aspects were taken into account. First, a common data model that is intended to become a new standard for PSHA was created; this is a milestone for data exchange also within the partners of SHARE. Second, benchmark tests comparing various PSHA codes were completed. According to the results, OpenSHA was considered the ideal platform for the development of the SHE as already envisioned in the proposal. Details of the benchmark tests can be found and/or requested from the GEM initiative or are available through the GEM document repository. The main motivations to choose OpenSHA are given by the GEM team:

- OpenSHA it's a "modelling environment for the development and testing of new SHA algorithms" [Field et al., 2003] rather than a classical PSHA software. In other words, OpenSHA is a library that provides all the basic "objects" needed to perform any SHA analysis rather than being a "black-box" software where the user interacts with the calculator only through an interface for the input definition. The major benefits of this approach are the *flexibility* in implementing different types of seismic hazard models (and if needed the ability to *easily* add new features), and the *transparency* of the calculator.

- OpenSHA went through an extensive public validation process (The PEER-Lifelines Validation of Software used in Probabilistic Seismic Hazard Analysis)

- OpenSHA was able to calculate complex PSHA input models (e.g. UCERF models, Field et al., [2005b] and Field et al., [2009]). This guarantees the capability to deal with most, if not all, the PSHA input model so far developed at a global scale.

- OpenSHA provides extensions for risk calculations (Field et al. [2005a]).

- OpenSHA includes support GRID computation.

- OpenSHA meets the main IT requirements: open source, modularity, flexibility and efficiency.

As previously mentioned, the SHE was developed starting from a **unified data model** that aims to balance generality and simplicity. The use of a unified data model has relevant advantages in the development of the engine; for example, the data model served to make proper use of the PSHA input models during the GEM prototype-project GEM1. Once a model is made available in this standardized representation through homogenizing procedure (parsing to shaML) it can be used for hazard calculation following a standard procedure and it can be send to a number of applications for its representation and/or the processing of its content (e.g. we can create shapefiles, a specific file format that can be read by the commonest Geographic Information Systems).

The present document is organized as follows. In the next Chapter we give a short description of the four source typologies adopted in the SHE. In the third Chapter we describe the way a PSHA input model is represented in the engine. Finally in Chapter 4 we illustrate the main features of the engine and with an example of the calculation workflow.

2 Seismic source typologies and their representation in the engine

Four principal source typologies represent geometry and seismicity recurrence properties of seismic sources used in the hazard engine. The main source typologies adopted in the current version of the engine are:

- Area sources
- Grid sources
- Fault sources
- Subduction sources.

The definition of source typologies was made following some basic assumption listed herein:

- The seismicity temporal occurrence model follows a Poisson process for all the typologies
- Annual rates of occurrence for discrete intervals of magnitude describe the seismicity occurrence properties; usually evenly spaced magnitude intervals of 0.1 units are used. This description admits flexibility and generality; indeed, this unique representation allows the description of several diverse magnitude-frequency distribution models.
- The four source typologies share some common properties; in adherence with this, a “parent” class (called *GEMSourceData*) was created that includes general properties and methods. This class was later on extended into child classes that correctly store typology-specific information.

The common parameters identified for all source typologies are:

- `Id` – Unique identifier for a source (for example, it can be the unique id used in the source model database to identify this area)
- `Name` – This field stores a short definition usually adopted to easily identify the source
- `tectReg` – This parameter specifies the tectonic region to which the source belongs to. We implemented the tectonic regions as they are used to characterize the Ground Motion Prediction Equations (GMPEs) in Work Package 4. The tectonic regions in the current implementation are:

- Active shallow tectonic region
- Stable continental region
- Subduction interface region
- Subduction intraplate region
- Volcanic region

In the following, we give a short description of each single source typology.

2.1 Area sources

Area sources are, by far, the most common typology used in the PSHA input model for SHARE. Area sources generally represent regions exhibiting the same seismotectonic regime and seismicity occurrence features. In PSHA, area sources are often modelled assuming that the seismicity is homogeneously distributed over their extent. It is common use that, for each area, the occurrence parameters are calculated by processing the subset of events (from regional, national or international catalogues) occurred within the polygon. This procedure frequently creates a trade-off between the need for small areas, so as to guarantee homogeneity in the underlying seismogenic process, and the necessity for large area sources so as to select large sets of events and – therefore – reliably compute the seismicity occurrence parameters.

In the scientific community it is widely accepted that area sources correspond to the crudest seismic source model. Nevertheless, their use is frequent because of the lack of information needed to consistently define more accurate representations of seismic sources and of the corresponding seismogenic process. One major criticism to area sources is their subjective choice through the definition of their geometry; a second criticism arises from the distribution of the event location in the area source – each event no matter of which magnitude can occur all over the region in contrary to any consideration about the tectonic structures. This is, indeed, one of the main motivations that fostered the development of grid models.

In the SHE, the information used to describe area sources is collected into the *GemAreaSourceData* - class. These are the main fields this class contains:

- `Reg` – This parameter identifies the relevant geographic region for a modelled area, i.e. the polygon bordering the area source. It corresponds to an array of locations described in terms of latitude, longitude [decimal degrees] and depth [km].

`magfreqDistFocMech` – This specifies the seismicity occurrence model. It consists of a list of discrete magnitude-frequency distribution (FMD) / focal mechanism (FM) pairs. Each FMD is represented by a bi-dimensional array storing mean annual rates/magnitude pairs. Each FM is defined by strike, rake, and dip angle (in degrees). With this approach multiple faulting regimes can be defined in the same area.

-

- `aveRupTopVsMag` – This field corresponds to an array of two columns and *n* rows. It specifies the depth to the top of rupture for discrete intervals of magnitude.

Magnitude	Depth to the top of rupture [in km]
6.0	5.0
6.5	0.0

- `aveHypoDepth` – This parameter specifies the average hypocentral depth [km] of ruptures with magnitude less that the minimum value contained in the `aveRupTopVsMag` array. Below this minimum magnitude, ruptures are treated as points and therefore no depth to top of rupture is given.

2.2 Grid sources

Grid sources can be considered a PSHA source model alternative to area sources. Both source typologies model distributed seismicity. Grid sources are usually derived from the application of seismicity smoothing algorithms [Frankel, 1996; Woo, 1996; Zechar, 2010]. The use of these algorithms carries some advantages compared to area sources, indeed, (1) they remove most of the unavoidable degree of subjectivity due to the definition of the geometries and (2) they define a seismicity spatial pattern that is, usually, more similar to reality. Nevertheless, some smoothing algorithms require a-priori definition of parameter values and optimization schemes that open the calculation to subjective choices.

Grid source models are implemented in the SHE simply as set of punctual sources. These are the fields used to characterize a point source:

- `hypoMagFreqDistAtLoc` – This object contains a list of magnitude frequency distribution/focal mechanim pairs for a single location. Conceptually, it is similar to the magfreqDistFocMech object for Area sources. The only difference is that in this case the list of magnitude-frequency distribution/focal mechanism pairs refers to a single location rather than to an extended region. Again, this feature is supported to allow multiple faulting styles in the same point.

- `aveRupTopVsMag` – same parameter as for Area sources;

- `aveHypoDepth` – same parameters as for Area sources;

2.3 Fault sources: shallow faults and subduction faults

Fault sources are by far the most scrupulous way to describe seismic sources; however, their correct definition in terms of geometry and recurrence parameters necessitate an amount of information currently only available in areas with clear surface evidences of faulting activity and high seismicity occurrence rates (e.g California, Japan, Turkey, Greece). Usage of fault sources is only desired if fault structures or networks can adequately be implemented in the SHE without too large uncertainties. In the SHARE hazard assessment process, individual seismogenic sources are collected in WP3 and clearly defined seismogenic sources will be included in the hazard calculation (see Deliverable 3.4). In the source data model, there are two fault source typologies; the first is normally used to describe simple shallow faults while the second one is used to model subduction interface faults. In the following we give a short description of the parameters characterizing these two typologies; as it can be clearly noticed they differ mostly in the way the fault surface geometry is described.

In the *GEMFaulSourceData*-class, these are the fields to describe a **shallow fault source**:

- `mfd` – This is a discrete magnitude-frequency distribution for this source (usually an interval width of 0.1 units of magnitude is used).

- `trc` – This is the trace of the fault; it corresponds to a set of locations defined in terms of latitude, longitude and depth.

- `dip` – This an the "average" dip angle of the fault (follows the Aki-Richard convention) [degrees]

- `rake` – This is the rake angle of the fault (follows the Aki-Richard convention) [degrees]

- `seismDepthLow` – This the lower seismogenic depth i.e. the lowest limit of the seismogenic interval along the fault surface [in km]

- `seismDepthUpp` – This the upper limit of the seismogenic interval [in km]

- `floatRuptureFlag` – This is just a flag used to specify if the ruptures must be floated along the fault surface or it must be assumed that each event ruptures the whole fault surface

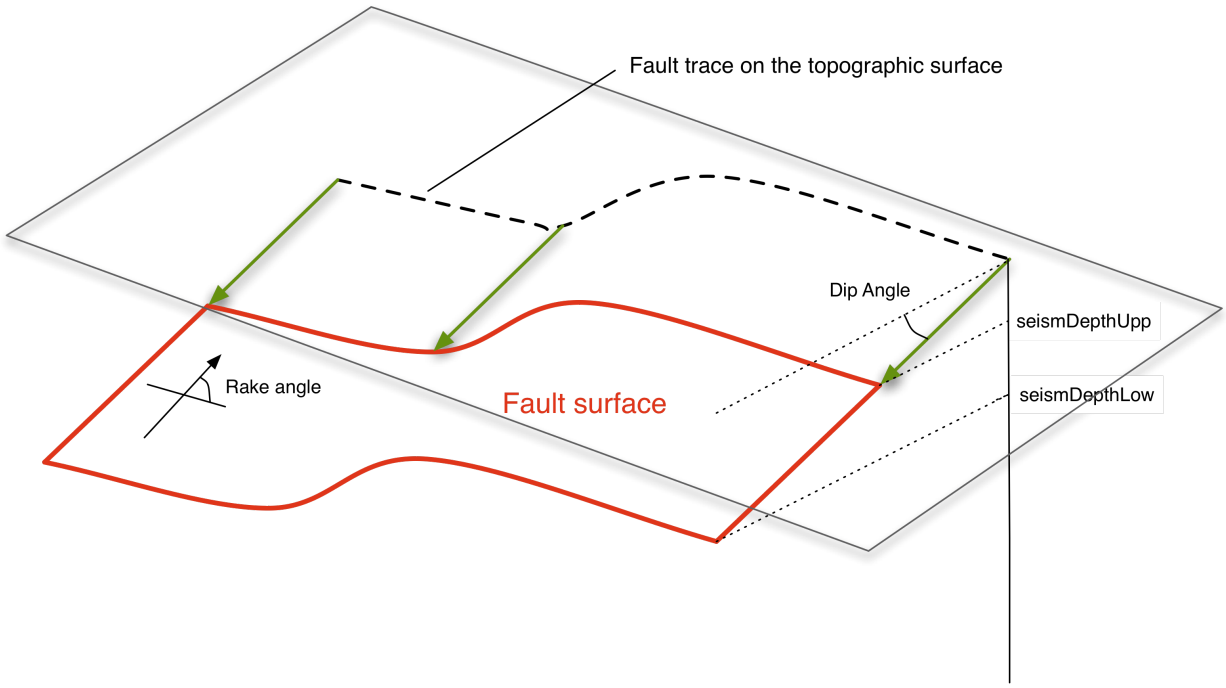

Figure 2-1 - Schema of a simple fault representation in the SHE. The black dashed line is the fault trace at the surface. The red lines are the borders of the fault surface. The green arrow shows the dip angle. On the right side of the picture the seismDepthLow and the seismDepthUpp are appropriately placed.

Figure 2-1 shows an example of the most important parameters involved in the definition and the creation of a simple fault. As it can be seen, the fault surface is created by the intersection between the surface obtained projecting the fault trace along dip and the iso-depth planes limiting at the top and bottom of the seismogenic crustal structure. This method is called the Stirling method (see www.opensha.org).

In the *GEMSubductionFaultSourceData*-class, these are the fields used to describe a subduction fault source:

- `mfd` – This is a discrete magnitude-frequency distribution (usually an interval width of 0.1 units of magnitude is used).

- `topTrace` – This is the upper trace of the subduction fault - it corresponds to a set of locations defined in terms of latitude, longitude and depth.

- `bottomTrace` – This is the bottom trace delimiting the subduction fault surface - it corresponds to a set of locations defined in terms of latitude, longitude and depth.

- `rake` – This is the fault rake (follows the Aki-Richard convention)

- `floatRuptureFlag` – This is just a flag used to specify if the ruptures must be floated along the fault surface or it must be assumed that each event ruptures the whole fault surface.

The implementation of the subduction zone source *GEMSubductionFaultSourceData* object has been successfully used by the GEM hazard team to model large interface subduction events currently defined in the USGS-NSHMP hazard models for United States, South America, and Indonesia. Intra-slab events are instead modelled as gridded seismicity.

There are more options for implementation: 1) smoothed seismicity boxes, 2) dipping volumes or others. The most appropriate ones need to be finally settled.

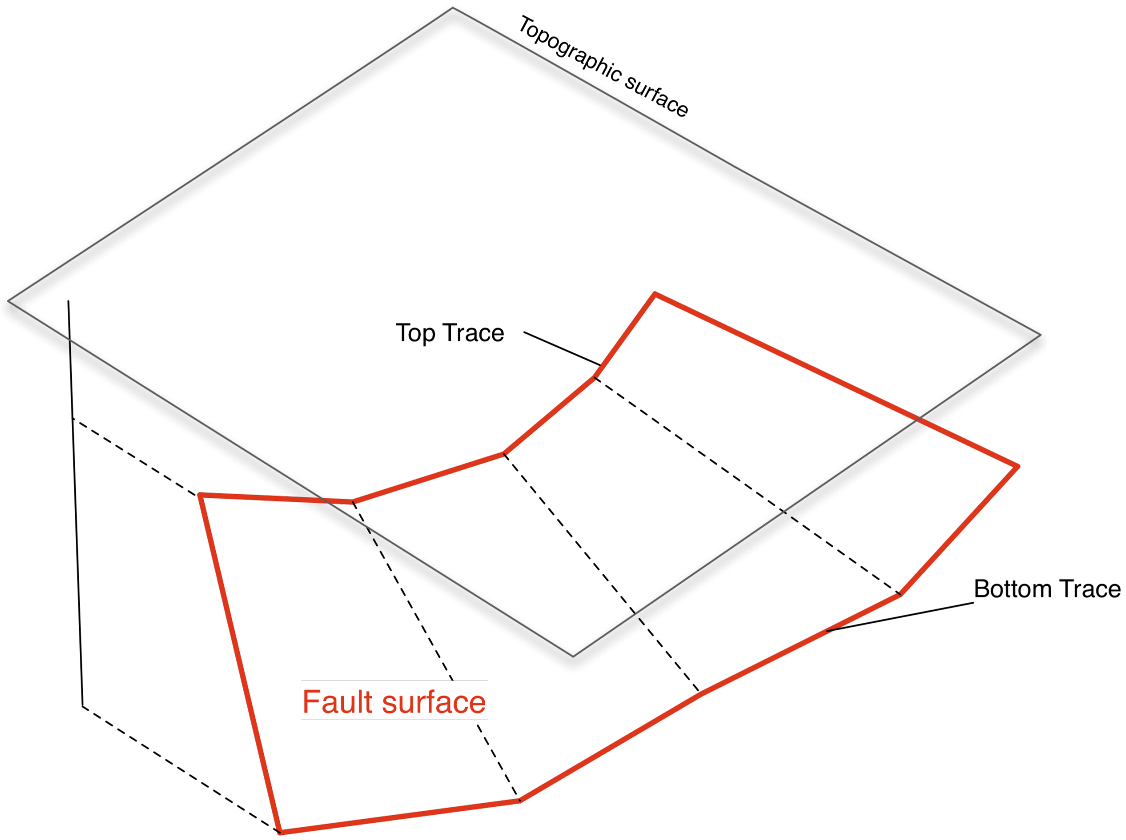

Figure 2-2 – Schematic representation of a subduction interface fault.

3 Seismic hazard models and their representation in the engine

Based on the definition and characterization of the source typologies, the next step is to create a comprehensive hazard model. The challenge in building a PSHA input model is the organization of sources into a comprehensive hazard model. For convenience, in the SHE all the models are organized in a logic-tree structure. The reference class is called *GemLogicTree*-class.

Note that for the PSHA input model, we define **two distinct logic trees**: one for the creation of the Earthquake Rupture Forecast (ERF) and one relative to the Intensity Measure Relation (IMR) or Ground Motion Prediction Equation (GMPE).

The SHARE logic tree design is subject to WP5 Task 5.3 and will result in deliverable D5.3 “Structure of the logic tree to be used in the hazard computation”. The efforts for the design structure and the implementation capabilities in the SHE are coordinated through combined workshops of WP5 and WP6 during the first year of the project.

3.1 Earthquake Rupture Forecast (ERF) logic tree

In case of a simple input model, i.e. a model that do not account for epistemic uncertainties, the information describing seismic sources is grouped into an array of *GEMSourceData* objects. The size of this array will correspond exactly to the number of sources included in the model.

In case of complex models, i.e. models that account for epistemic uncertainties related to the creation of an ERF, an object that is capable to fully describe the structure of the logic tree exists. Note that in the current version of the engine, we do not support logic trees with uncorrelated branching levels. For calculation purposes, the defined logic tree data structure simply stores one *GEMSourceData*-object for each end branch of the logic tree. With uncorrelated uncertainties we mean uncertainties that do not apply in the same way to all sources. For example, if a given fault system is subject to uncertainties in the dip angle, so that 3 possible values of dip are allowed (say 40, 50, 60), correlated uncertainties means that ALL faults in the system may have 40, or 50, or 60 degree dip, uncorrelated uncertainties means that in the system SOME faults have 40, some 50, some 60 degree dip. Clearly if the fault system is large (many faults) enumerating all the possible combinations is not possible, so a Monte Carlo approach is probably the only feasible way to compute a number of realizations of fault systems from which a mean hazard map can be computed

Figure 3-1 shows an example how the SHE stores logic trees. It is evident that the central element used to describe the structure of a logic tree is an object called GEMLogicTreeBranchingLevel. Each branching level contains one or more branches and each single one is characterized by a parameter value and a weight. In the example of Figure 3-1 we put two branching levels, one accounting for epistemic uncertainties related to fault geometries the other used to specify two possible depths of the top of rupture. Within our logic tree model, branching levels can be combined to create any desired tree structure (for an example, see the lower part of Figure 3-1).

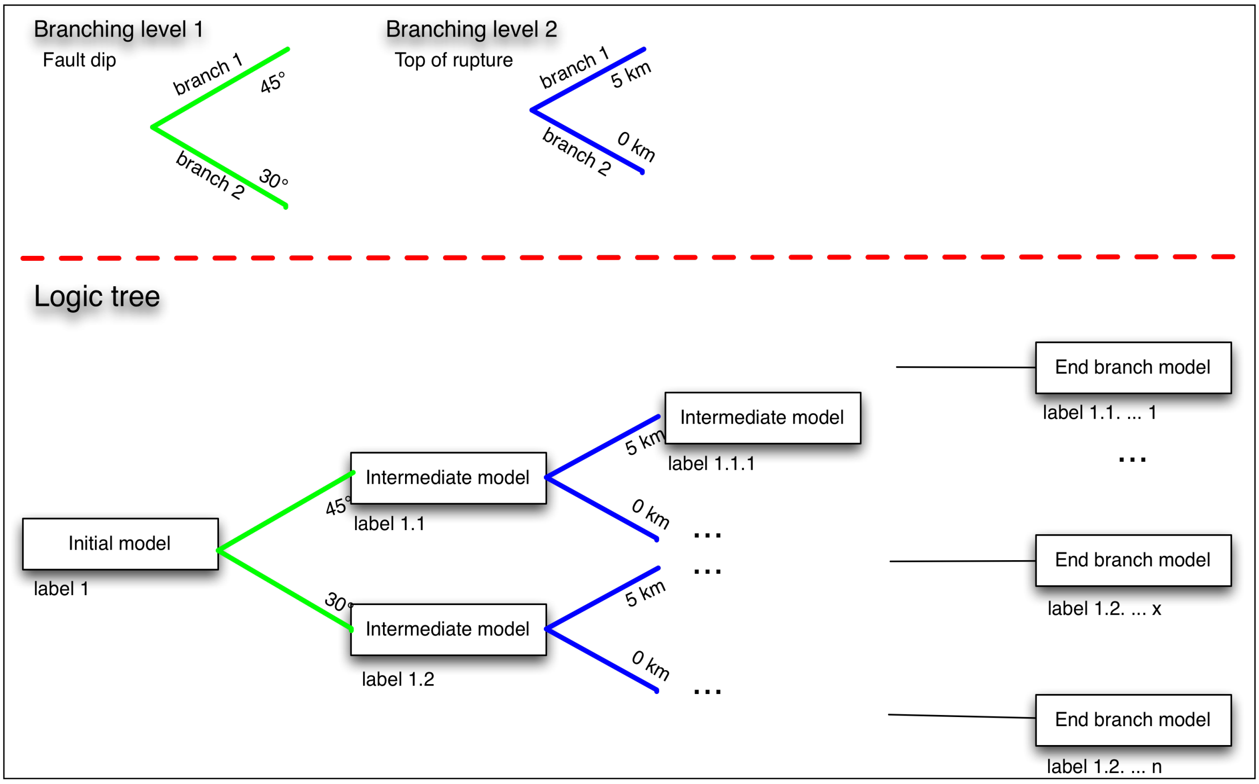

Figure 3-1 – Example of the structure of a logic tree as used in the SHE. The upper part of the figure shows the definition of two branching levels used to create the logic tree. The lower part of the figure shows the structure of the logic tree obtained by combining the initial PSHA input model and the branching level defined as represented in the upper part of the figure.

3.2 Intensity Measure Relation (IMR) logic tree

In parallel to the definition of ERF logic trees, the SHE provides the option of creating a logic tree to account for epistemic uncertainties related to IMRs. In this case, there will be a hash map of IMRs associated to each end branch of the logic tree; each hash map contains as many IMRs as the number of tectonic regions considered in the model. This data structure maps the correspondence between each tectonic region and IMR, i.e. given a source belonging to a specified tectonic region the code is capable to immediately use the appropriate IMR to calculate the hazard at the site.

Table 3-1 shows an example of the content of such hash map of IMRs; as it can be noticed it describes two end branches of a simple logic tree. The difference in the content of the two arrays is just in the IMR used for seismic sources belonging to active shallow tectonic regions.

Table 3-1 – Example of the content of one Hash Map used to specify the two end branches of an IMR logic tree.

End-branch 1.1 – weight 0.5	IMR for active shallow tectonic regions	Boore and Atkinson (2008)
	IMR for stable continental regions	Atkinson and Boore (2006)
	IMR for subduction sources	Zhao et al. (2006)

end-branch 1.2 – weight 0.5	IMR for active shallow tectonic regions	Chiou and Youngs (2008)
	IMR for stable continental regions	Atkinson and Boore (2006)
	IMR for subduction sources	Zhao et al. (2006)

4 Seismic Hazard Engine: Main components and calculation workflow

The SHE is organized into a group of packages. Figure 4-1 shows a screenshot of a portion of the IDE tool (Eclipse, see also [2]) used by the hazard team for programming the engine; in particular, the figure shows the main structure of the packages containing the classes composing the engine. The computational core is contained in the **calc** package, the **data** package includes the original ASCII input files of the PSHA input models collected so far, the **results** package groups the output ASCII input files (the **local, commons**, and **util** packages contain general classes for the calculation engine).

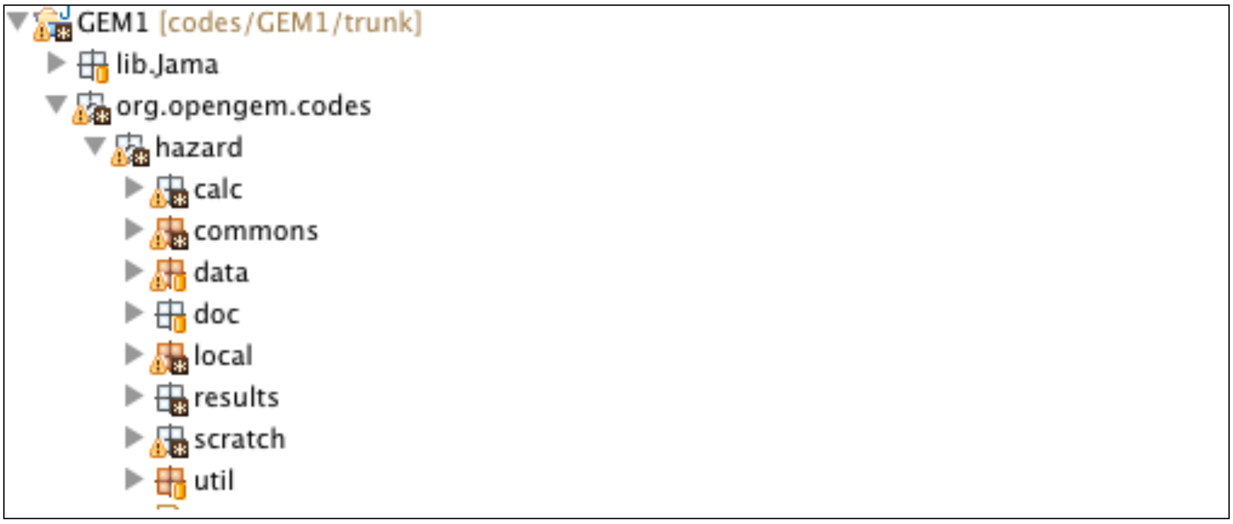

Figure 4-1 - Package structure of the SHE project.

Entering into a major detail, the calc package is furthermore organized into sub-packages; Figure 4-2 shows the structure of sub-packages. The real calculation core resides in the **GemHazardCalculator** package. **GemModelData**, **GemModelParsers** and **GemLogicTree** are the main packages needed to describe a PSHA input model.

The input models - mostly on ASCII format - are read with Java parser that resides in the **GemModelParsers** package. The **GemLogicTree** package contains the main Java classes for constructing the logic tree of the models, including logic tree for IMR (or GMPE), logic tree API and logic tree branching.

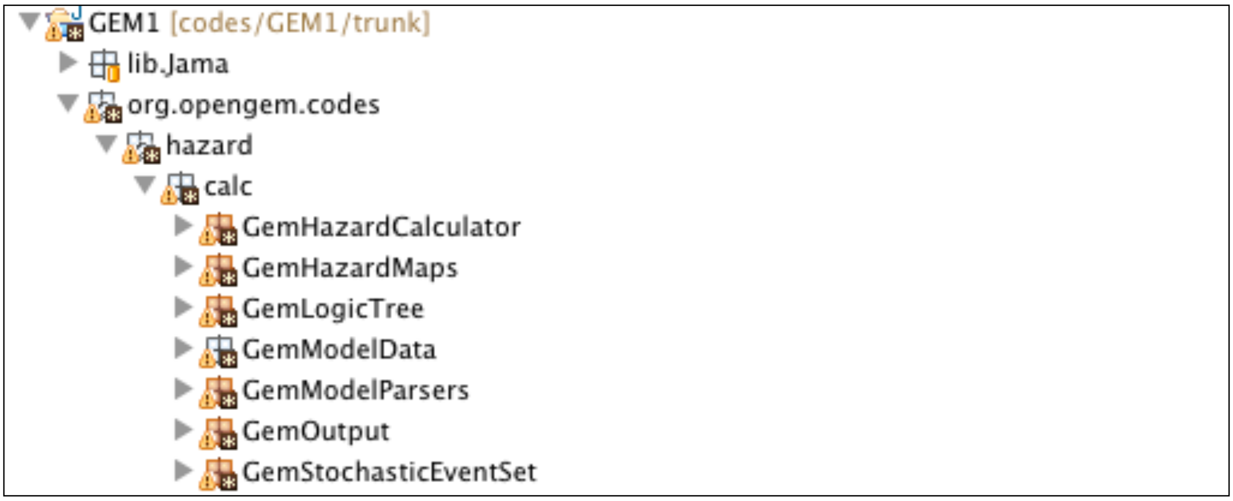

Figure 4-2 - `calc` package: sub package structure description

4.1 An example of calculation workflow

In order to give a description of the typical hazard calculation workflow let's consider a very simple PSHA model, whose original information is made available as an ASCII input file. We want to use this model to calculate seismic hazard curves for an investigation time of 50 years in a specified area covered by the PSHA input model.

The first step in the hazard calculation workflow is to create a parser class i.e. a piece of code capable to read the information contained in the original ASCII input file and to convert it in a format compatible with the seismic source data model. More in detail, the parser takes the information describing each source in the input file and appropriately accommodates it into the fields belonging to the fitting source typology. In case the model is residing in a database (DB) instead of an ASCII input file, the parsing process can be simply substituted by a query. In either case, the final result of this initial step can be considered an array of *GEMSourceData*. In the SHE, for convenience, we represent all the models using a logic tree data structure; in our case the ERF logic tree will have a single branch (1.0 weight) within one single branching level.

Immediately after the creation of the source data array and the ERF logic tree, it is necessary to create the IMR logic tree. In case all seismic sources belong to the same tectonic region and epistemic uncertainties are not considered the logic tree will simply require one IMR.

Additional information required to lunch the calculation are the set of sites of interest (i.e. list of sites where hazard curves have to be calculated), and the type of expected results (e.g. the intensity measure type (PGA, PGV, SA,…), probability of exceedance for hazard maps (2%, 10%) in the given time period). Once the engine receives this information the calculation is performed without any additional supervision.

In case of a model based on a logic tree, the engine will generate as many hazard curves files as the number of end branches plus mean hazard curves computed using the information in the logic tree structure and, if requested, mean and median hazard maps.

Regarding the practical execution of the calculations, the SHE supports multi-threading to make use of the large multi-core (up to 32 CPUs) shared-memory machines available. However, computational time is still an open issue, and work is in progress to minimize the overall execution time.

An example of hazard calculation for Europe using the newly developed SHE and following the above mentioned processes is presented in Figure 4-3. The hazard calculation is based on the preliminary model submitted by Grünthal et al. 2010 for GEM1-project. The hazard model consists of 435 seismic sources distributed across Europe. The seismic source typology predominant on this model is the area source typology. Spatial distribution of the seismic sources, together with the depth distribution is presented in Figure 4-4 . The information related to the geometry of the sources was provided as a shape file- ESRI based- format accompanied by an input file – excel – based format describing the seismicity parameters of each seismic source. The information contained in both files was retrieved using a Java parser, called Europe2GemSourceData and converted in objects that are passed to the calculation process, as well as used to transfer the information to the database. Several difficulties were encountered working with the received files, including “empty” seismic sources and/or misleading IDs, “donut” area sources have connected inner and outer boundaries. This type of sources can be accommodated only if the inner and the outer boundaries are not connected. Plotting the spatial distribution of the seismic sources together with various geometry and seismicity parameters, such as hypocentral depth, Gutenberg-Richter a- and b-values, maximum magnitude, was a first validation process in order to overcome the ambiguous information. This experience acknowledges the need of a standardized form for communicating the input model for hazard calculation. The settings of the hazard calculator are defined as a main type Java class, arbitrary named RunEurope, and include (i) definition of the region for calculation and the level of discretization; (ii) setting the logic tree for the IMR (or GMPEs); (iii) declaration of the probability level for computing the hazard, (iv) setting the number of CPU; (v) choosing the type of output, (vi) declaration of the output path for results storage. The hazard calculation was done using a multi-core (32CPU) SUN machine and the total execution time was about 33 hours.

Herein, it has to be strongly emphasized that the seismic hazard map in terms of PGA, for a 10% probability of exceedance in 50years, presented in Figure 4-5, has a ***proof of concept*** statement. The values presented are not necessarily accurate and one has to treat them accordingly.

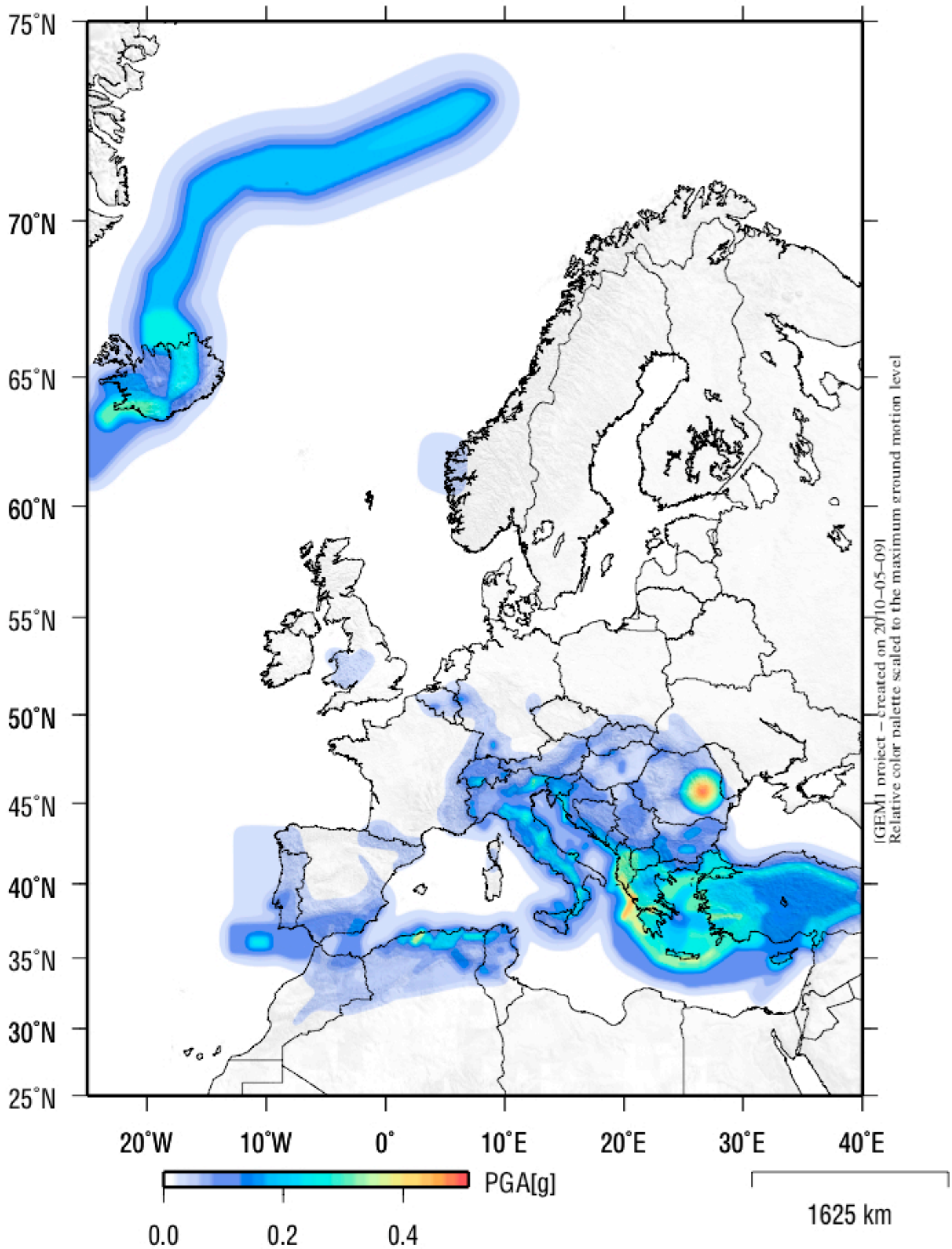

Figure 4-3: Seismic Hazard Map in terms of PGA, for 10% probability of exceedance in 50 years, based on the preliminary input model prepared by Grünthal et al 2010. This map is produced as a "*proof of concept*" and values do shown should not be used further.

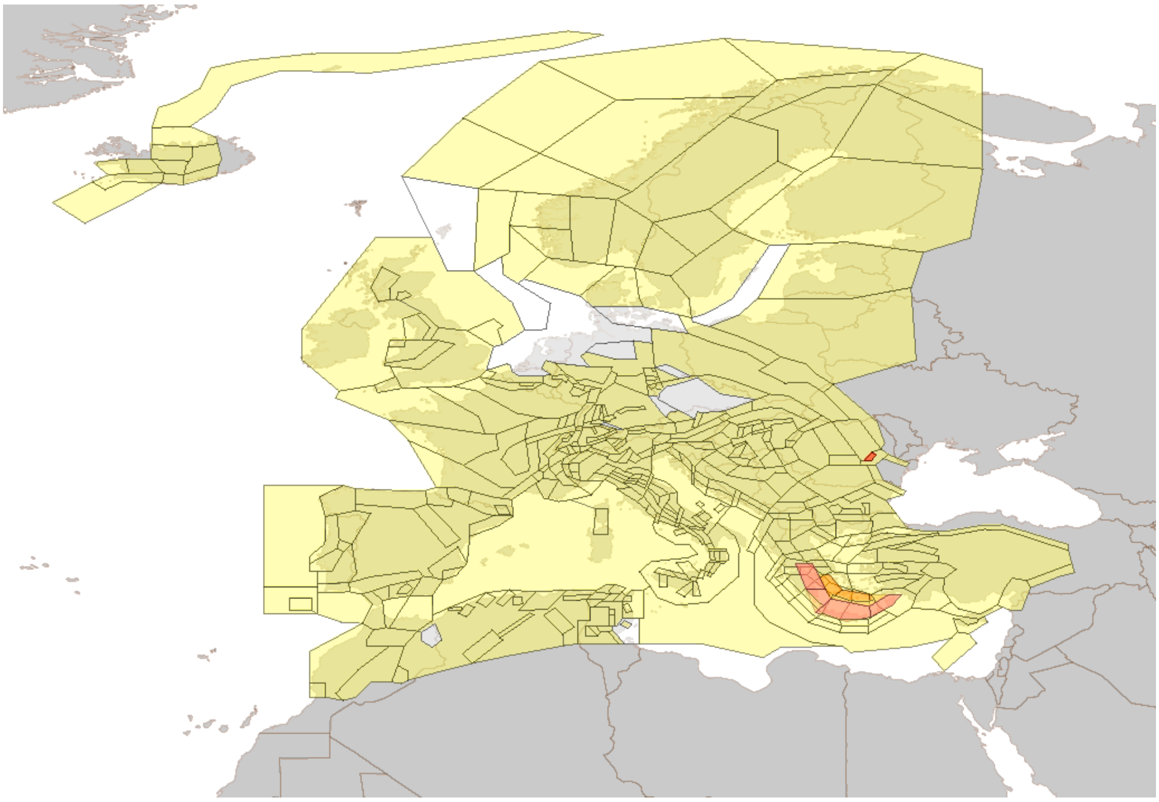

Figure 4-4 : Spatial distribution of seismic sources across Europe as a function of depth parameter. Yellow are the shallow depth sources, whereas the red are intermediate depth sources.

In the current status, the SHE is ready to be fully integrated in the OpenGEM system (depicted in Figure 4-5) the GEM framework also adopted by SHARE. A partial integration has been already achieved: tools for the creation of XML files (following the shaML schema) have been developed and their use allows the input and output data contained in standard java “objects” to be transferred to both the Presentation Tier and the Data Tier in an automated fashion.

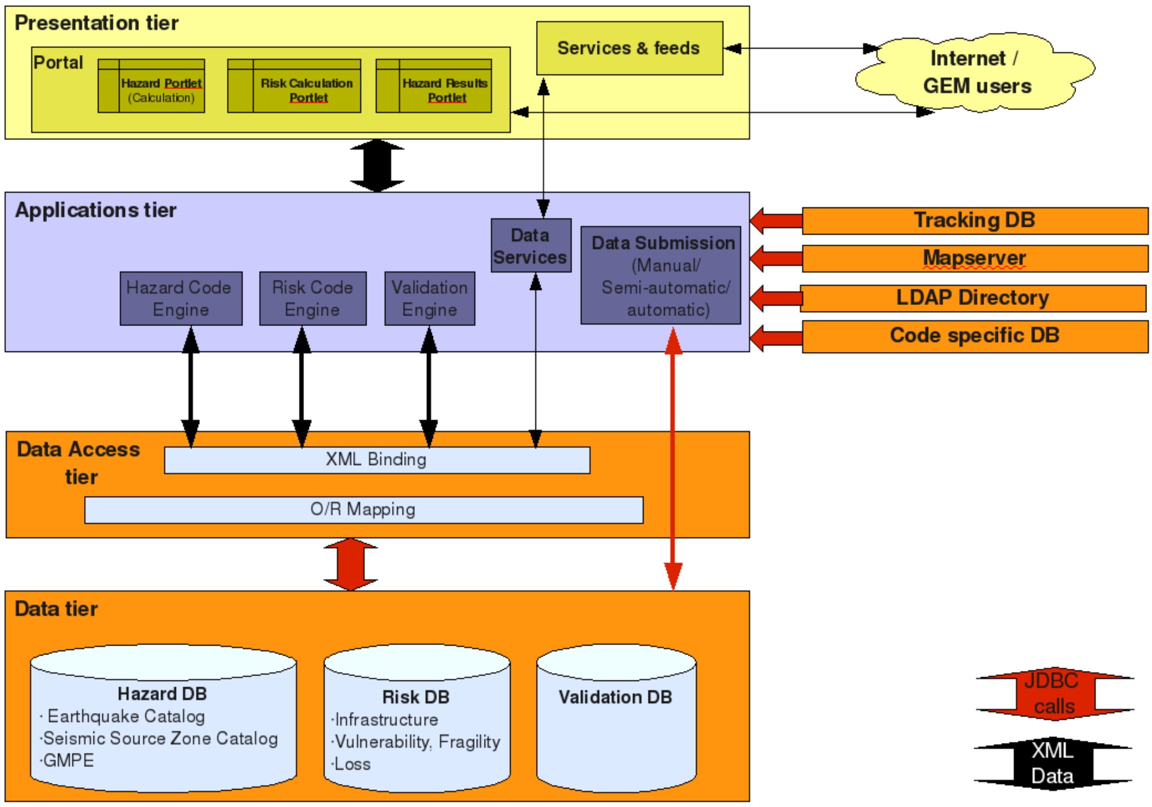

Figure 4-5- The overall computational infrastructure and the SHE shared by GEM and SHARE.

5 Outlook and Open Issues

The current SHE is the first step in the development of a complete and powerful tool that is already able to perform large end-to-end calculations. This was shown in the GEM1-prototype project (see GEM documentation on www.globalearthquakemodel.org). Enhancements and improvements are foreseen that will be implemented in a combined synergetic effort of SHARE and GEM. Activities are ongoing to customize the SHE in order to fulfil the hazard input/output requirements specified on various documents delivered within each work-package. More precisely, the efforts are concentrated on:

- INPUT
  - Define the input file format for communicating the information along the community (shaML);
  - Internal quality control of the received input data for seismic sources;
  - Provide the capability of implementing all source typologies discussed on previous sections;
  - Implementing the set of GMPE recommended within WP4;
  - Test the proposals on using the GMPEs for different given magnitude-distance ranges.
  - Logic tree and Sensitivity analysis

- OUTPUT
  - Implement the EC8 requirements for SHARE specified on the preliminary report prepared by Costa A. C. et al (2010); A synthesis of these requirements, as were advised by SHARE WP2 are presented in Table 1 of the aforementioned report.
  - Implement and test a solution to generate Uniform Hazard Spectra (UHS), because for each GMPE the spectral ordinates might not be uniformly sampled.
  - Improve the disaggregation module in order to indentify the controlling earthquake scenario as is defined in Eurocode 8;
  - Produce "proof-of-concept" hazard maps in terms of PGV and PGD, as well as on Spectral Acceleration (SA) and Spectral Displacement (SD)
  - Introduce and investigate the concept of Local Amplification Factor (F_0) and corner periods T_C/T_D, as parameters that are requested to define the seismic action in Eurocode 8 and need to be output from the hazard analysis;
- TECHNICAL
  - Improvement of calculation efficiency: Accurate profiling of the implemented Java-classes can be used to find possible bottlenecks in the calculation workflow. Currently, area source- and grid seismicity source-based models are associated with the largest computation times. More efficient implementation of these two

source typologies and/or development of customized calculator could provide better performances.

- Work on reducing computation times (many possibilities here, some of which might require fairly major code revisions, such as changing the representation of finite-rupture surfaces).

- Management and routine maintenance (modify class names, inheritances, package structures, etc. to keep things as simple as possible and/or to accommodate new needs).

- Providing a user manual to enhance usability of the SHE.

- On a long term, development of a “suite” of basic tools (i.e. tools for input file generation, logic tree visualization, sanity check of input files, etc.)

The development will need to keep strongly coordinated between the ongoing and future projects. Managing the requirements for different regions and purposes remains an ongoing task.

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Website references

1. OpenSHA

A community-modeling environment for seismic hazard analysis.

[Available at http://www.opensha.org]

2. **Eclipse**

An open development platform comprised of extensible frameworks , tools and runtimes for building, deploying and managing software across the lifecycle

[Available at http://www.eclipse.org]