Julius-Maximilians-
UNIVERSITÄT
WÜRZBURG

LIMBO Tutorial
An Eclipse-based Tool for Modeling of Load Variations

Jóakim Gunnarsson v. Kistowski

Department of Computer Science
Chair for Computer Science II
Software Engineering

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Contents

1. LIMBO Tutorial

LIMBO requires an up-to-date version of the Eclipse Modeling Tools. It has been tested with Eclipse Kepler, Luna, Neon, and Oxygen. LIMBO should also work with any newer Eclipse Version. We generally recommend using the newest available version. The newest version at the time of the latest update to the tutorial is available at:

`http://www.eclipse.org/downloads/packages/eclipse-modeling-tools/oxygenr`

Eclipse must be running using Java 6 or newer.

1.1 Installing LIMBO

There are two ways to gain access to LIMBO:

1.2 Installation via Update Site

LIMBO can be downloaded from its Eclipse Update Site at:

`http://se2.informatik.uni-wuerzburg.de/eclipse/limbo/`

To use this site click on **Help** → **Install new Software ...** in the Eclipse IDE, then click the **Add...** Button and enter the URL there. The site can then be selected in the **Work with:** drop-down menu and the feature should appear (Fig. 1.1).

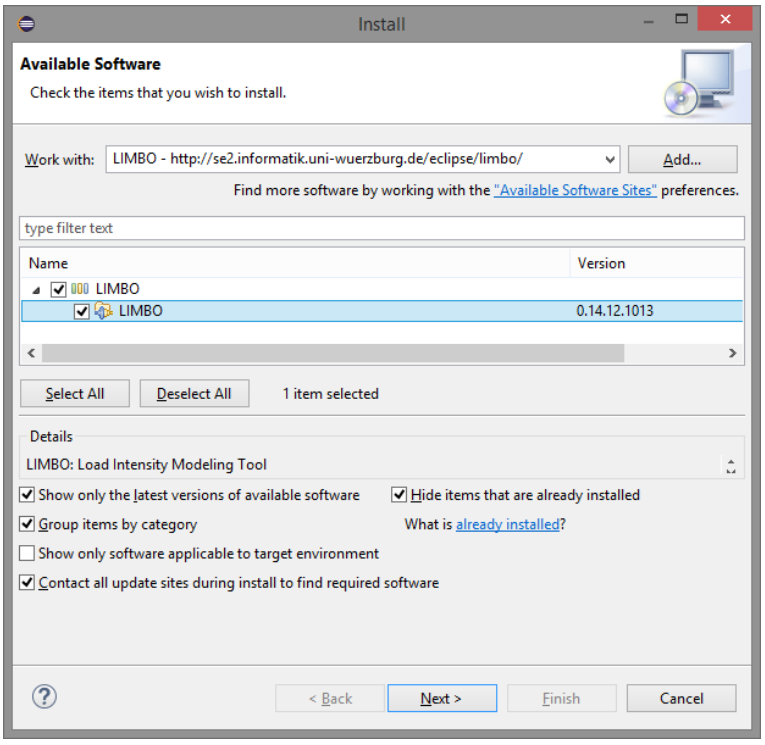

Figure 1.1: The *Install new Software ...* dialog, with LIMBO selected.

1.2.1 Building LIMBO from Code

The feature can also be built directly from Code, available on GitHub at

`https://github.com/joakimkistowski/LIMBO`

by checking out the following plugin projects:

```
https://github.com/joakimkistowski/LIMBO/tree/master/dlim.exporter
https://github.com/joakimkistowski/LIMBO/tree/master/dlim.extractor
https://github.com/joakimkistowski/LIMBO/tree/master/dlim.generator.edit
https://github.com/joakimkistowski/LIMBO/tree/master/dlim.generator.editor
https://github.com/joakimkistowski/LIMBO/tree/master/dlim.generator
```

LIMBO can then be executed by right-clicking on any of the projects and choosing **Run As → Eclipse Application**.

Please note: This tutorial is a LIMBO user tutorial. If you intend to develop Eclipse plugins for LIMBO or using LIMBO, please refer to the LIMBO Architecture description here:
`http://se2.informatik.uni-wuerzburg.de/pa//uploads/papers/paper-771.pdf`.
An even further in-depth description of LIMBO's code structure can be found in here:
`http://se2.informatik.uni-wuerzburg.de/pa//uploads/papers/paper-749.pdf`
(pages 37-51)

1.3 Creating a new Model

A new Descartes Load Intensity Model can be created within the context of any Eclipse Project of any project type (Using separate projects for DLIM modeling is recommended).

To create a new model instance click **File** → **New** → **Other**; in the dialog choose: **Descartes Load Intensity Model** → **Descartes Load Intensity Model** and click **Next >** (Fig. 1.2). Now select the project in which to place the model and enter a name.

The model creation wizard (first page in Fig. 1.3) allows for easy creation of an initial model with the use of parameters (as defined by the hl-DLIM meta-model) for the different parts of the model. This will be done during the course of this tutorial. Click on **Next >** to get to the next wizard page. It can however be skipped at any point by clicking the **Finish** button.

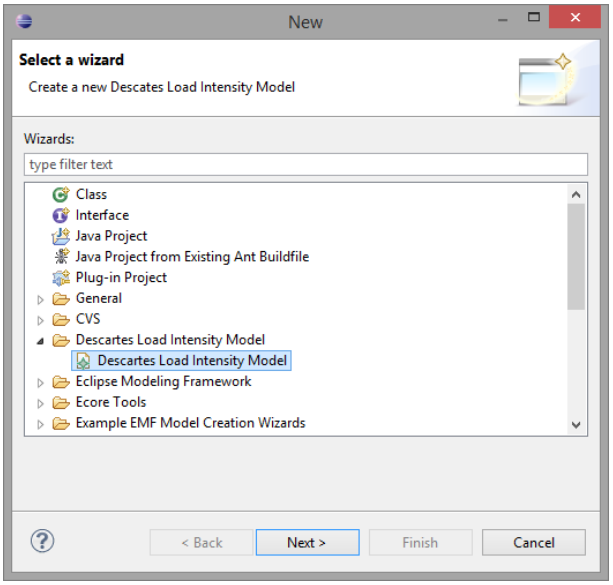

Figure 1.2: Choosing the DLIM creation wizard.

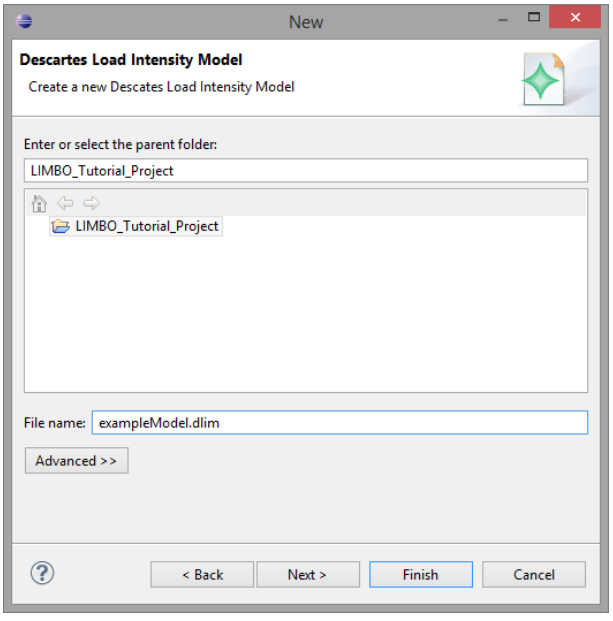

Figure 1.3: Creating a new model.

The next dialog page (Fig. 1.4) offers a choice about which model parts to edit in the

wizard. We can extract the wizard's parameters from an arrival rate trace and modify the seasonal, trend, burst, and noise parts of the model. For now we leave this page at its default settings (**Extract Model Parameters from Trace** unchecked, everything else: checked) and click on **Next >**.

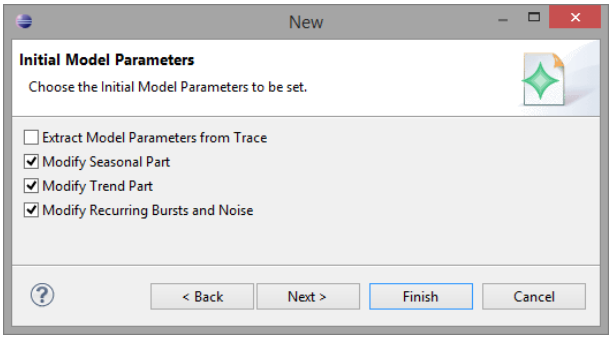

Figure 1.4: Choosing which parameters to edit.

1.3.1 Modifying the Seasonal Part

This dialog page (Fig. 1.5) offers to define the model's seasonal part. The seasonal part is the repeating base function of the model. It is defined by its arrival rate peaks and base values, as well as its period (duration of a single seasonal iteration). I recommend playing around with the parameters to get a feel for them. In the end set them as follows:

Period:	24
Number of Peaks:	2
Base Arrival Rate Level:	2
Base Arrival Rate Level between Peaks:	4
First Peak Arrival Rate:	12
Last Peak Arrival Rate:	11
Interval containing Peaks:	12
Seasonal Shape:	SinTrend

Then click on **Next >**.

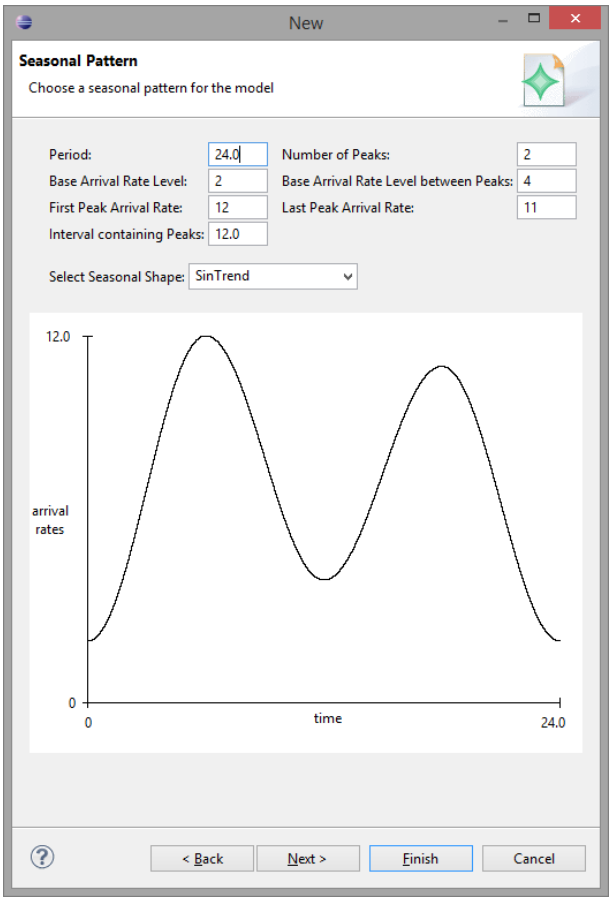

Figure 1.5: The Seasonal Part.

1.3.2 Modifying the Trend Part

This dialog page (Fig. 1.6) defines the model's trend part. The trend part defines a piecewise function, which interpolates at the maximal seasonal peaks so that these peaks reach the target arrival rate defined in the list view. Each trend segment stretches over multiple seasonal iterations and interpolates between these defined target peaks.

The trend segment length is defined by the **Number of Seasonal Periods within one Trend**. Set this to **2**.

Next we must define the target arrival rates which the seasonal peaks are to reach:

In the text-field next to **Interpolate max. seasonal peak to target arrival rate:** enter **12**, then klick the **Add** button. The first trend segment now begins at the biggest peak of the first seasonal iteration. This peak has an arrival rate of 12.

Next enter **20** in the same text-field and click **Add** again. The first trend segment will end by interpolating the maximum arrival rate of its last seasonal iteration (remember: the segment stretches over 2 seasonal iterations) to the arrival rate of 20.

At last enter **16** and click **Add** again.

As the **Trend Shape** select **SinTrend**. This is the function the trend uses for interpolation between its defined arrival rates.

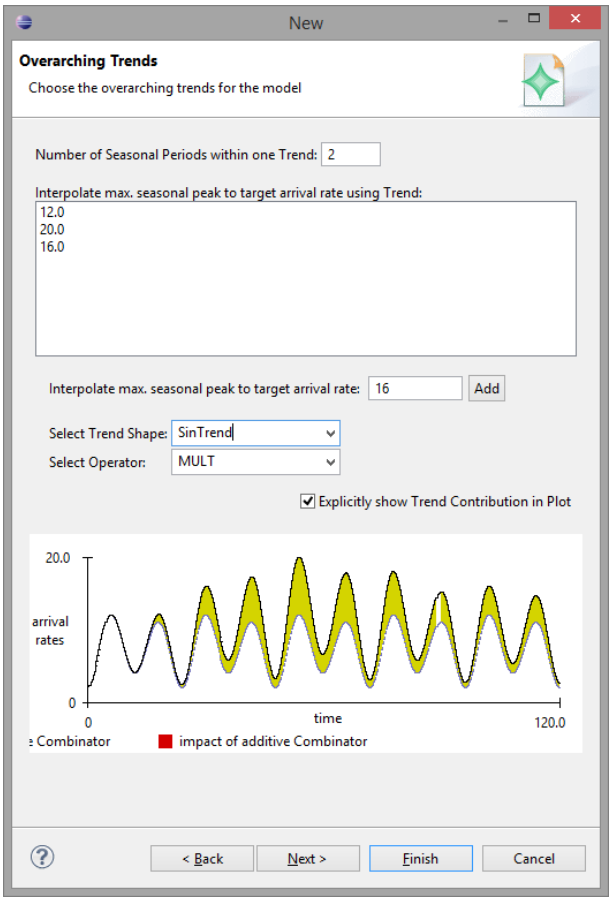

Figure 1.6: The Trend Part.

Click **Next >**.

1.3.3 Modifying the Burst and Noise Parts

The last dialog page (Fig. 1.7) offers the definition of recurring bursts and random noise. Both are added onto the existing arrival rate output.

Define the bursts as follows:

First Burst Offset:	18
Inter Burst Period:	72
Burst Peak Arrival Rate:	10
Burst Width:	4

Additionally set the **Maximum Noise Arrival Rate** to **3**.

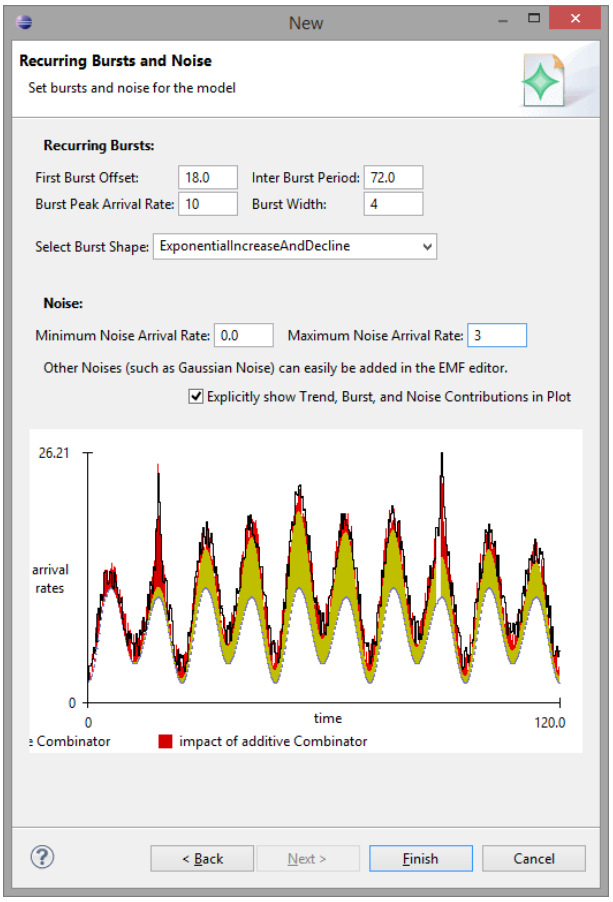

Figure 1.7: The Burst and Noise Parts.

You are now done. Click **Finish** to exit the wizard.

1.4 DLIM Editor

The DLIM Editor opens automatically (Fig. 1.8). The model should already be pre-populated with a root *Sequence*, a number of *TimeDependentFunctionContainers*, and a few *Combinators*.

It is recommended to turn on Live Validation for easy modeling feedback, by right-clicking inside the editor and checking **Live Validation**. Model element attributes can be changed in the Properties View, which can be opened by right-clicking on any model element (such as the root *Sequence*) and selecting **Show Properties View**. You should also open the Plot View, which visualizes the model's current arrival rate function. Do this by right-clicking anywhere in the editor and the clicking on **Show Plot View**.

Rearrange the Plot View and Properties View so that both are accessible at the same time.

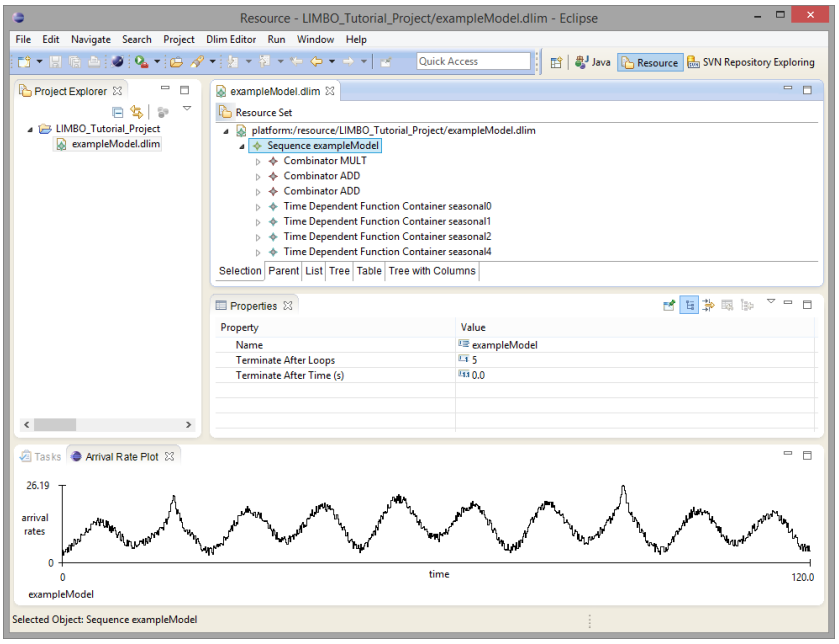

Figure 1.8: The initial model.

1.4.1 Plot View

Right-clicking in the Plot View offers a few options. You can save the current plot to a file or display arrival rates from a trace for comparison.

For now, toggle the plot decomposition by clicking on **Toggle Decomposition**. The decomposition shows the impact of the different *Combinators* on the total arrival rate function.

The plot view context menu also offers options to save the displayed plot as a .png image, and it can optionally display arrival rates as defined by an arrival rate trace (see Section 1.4.5).

1.4.2 Editing a DLIM instance in the Editor

All functions displayed in the DLIM editor can be deleted or edited. For this tutorial we are going to delete the uniform noise function and replace it with a normal noise distribution. We are then going to multiply a linear function onto this noise, so that it is strongest at the beginning and then fades out towards the end.

The *Uniform Noise* is contained in the third *Combinator* (The second *Combinator ADD*). Open this *Combinator*, then click on the *Uniform Noise* and delete it. The editor will now display an error, if Live Validation is enabled (Fig. 1.9).

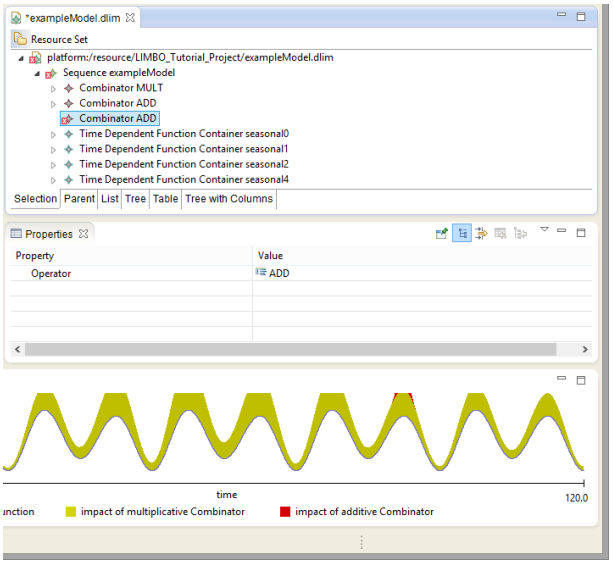

Figure 1.9: Our model with the Uniform Noise deleted.

Next add a *Normal Noise* to the *Combinator*. For this right-click on the *Combinator*'s then **New Child** → **Normal Noise** (Fig. 1.10).

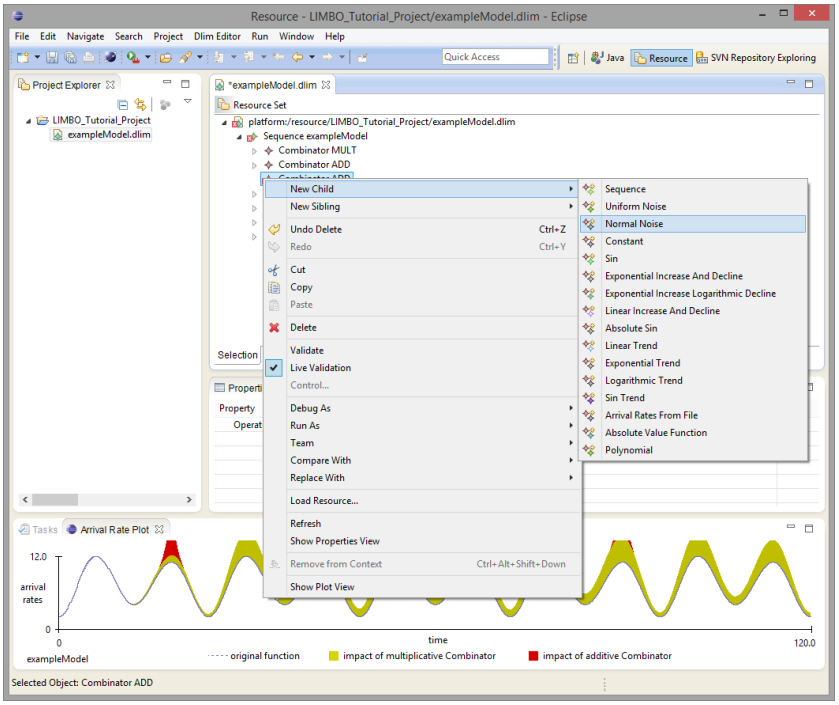

Figure 1.10: Creating a new model element.

To edit the new *Normal Noise* select it (click on it), then change its attributes in the Properties View. Set its **Mean** to **5** and its **Standard Deviation** to **3** (Fig. 1.11).

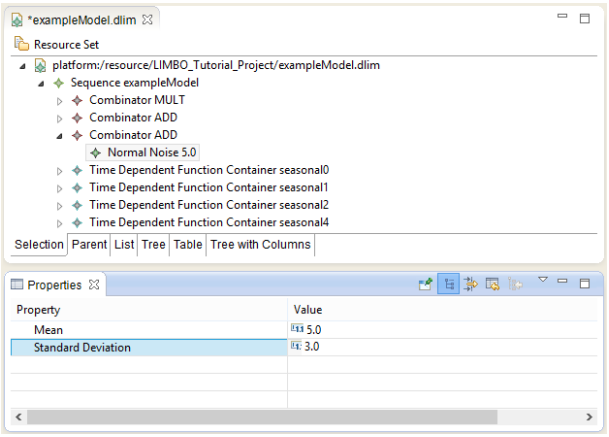

Figure 1.11: Editing the Normal Noise.

Next we add a *Combinator* to the *Normal Noise*. Right-click on the *Normal Noise* → **New Child** → **Combinator**. Set the new *Combinator*'s **Operator** to **MULT** in the Properties View.

We now add a *Linear Trend* to the new *Combinator*. Right-click on the *Combinator* → **New Child** → **Linear Trend**. In the Properties View set the *Linear Trend*'s **Function Output At Start** to **1** and its **Function Output At End** to *0*.

We have now successfully replaced the original *Uniform Noise* with a linearly diminishing *Normal Noise* (Fig. 1.12).

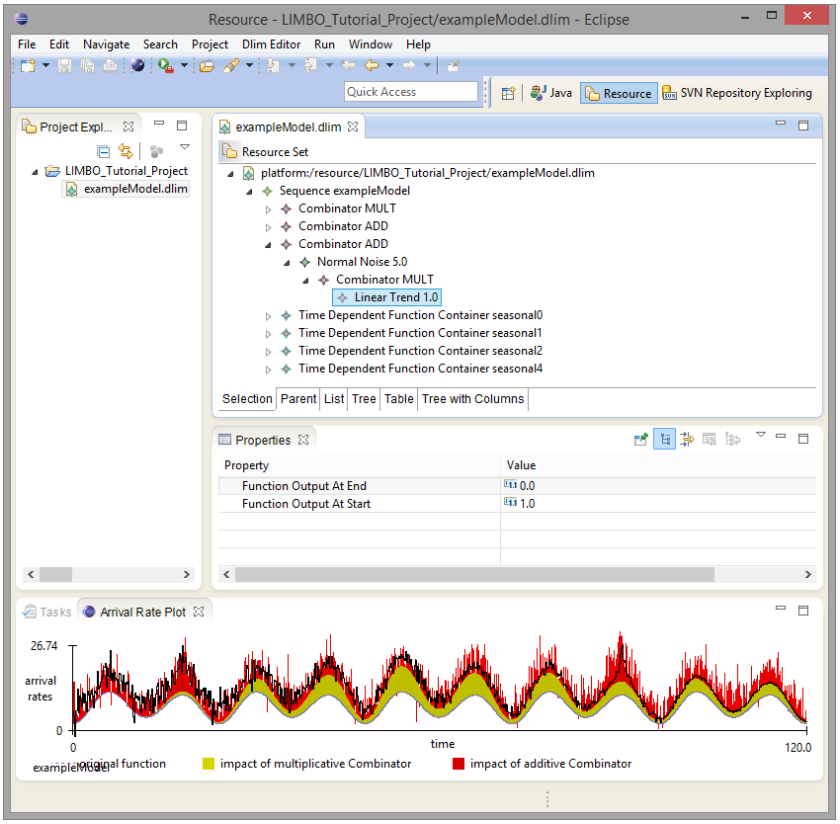

Figure 1.12: The edited Model.

1.4.3 Generating Time Stamps

Once no validation errors appear and the model has been saved (**ctrl+s**), a request time-stamp series can be generated by right-clicking the .dlim model file in the Eclipse Package Explorer and selecting **Generate Time Stamps** (Fig. 1.13). A list of all currently installed time-stamp exporters appears. All default exporters, shipped with LIMBO write their resulting time series to their respective folders within the model's Eclipse project.

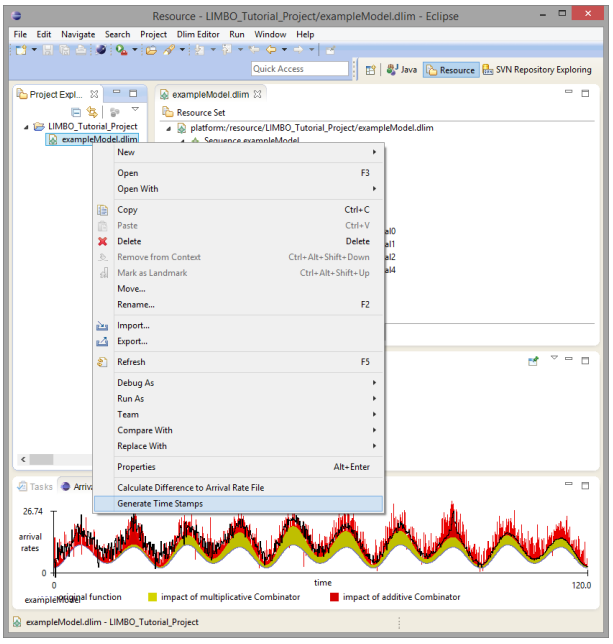

Figure 1.13: Generate Time-Stamps.

For this tutorial we want to create request time stamps for the use with a benchmarking framework. For this, the time-stamp generator samples the arrival rate function and then generates time-stamps according to the sampled arrival rate within each sampled interval. Select **Request Time Stamps via Equal Distance Sampling**, then click **OK**. This creates the request time-stamps with an equal distance from each other within each sampled arrival rate interval.

The resulting dialog offers a number of parameters with which to change sampling interval, the time over which the function is defined, and other parameters. The default parameters are fine for now. Click on **OK** to generate the time-stamps. A .txt file appears in the *timeStamps* folder in the .dlim file's Eclipse project.

1.4.4 Extracting a DLIM Sequence from a Trace

Next we are going to extract a *Sequence* from an existing arrival rate trace. For this we use an arrival rate trace from the German Wikipedia. Download it here:

`http://se2.informatik.uni-wuerzburg.de/files/wikipedia_trace.txt`

The extraction process takes a DLIM *Sequence* and fills it with model elements modeling the arrival rates defined in the trace. **Right-click on the model's root *Sequence* → Extract Sequence from Arrival Rate File** (Fig. 1.14).

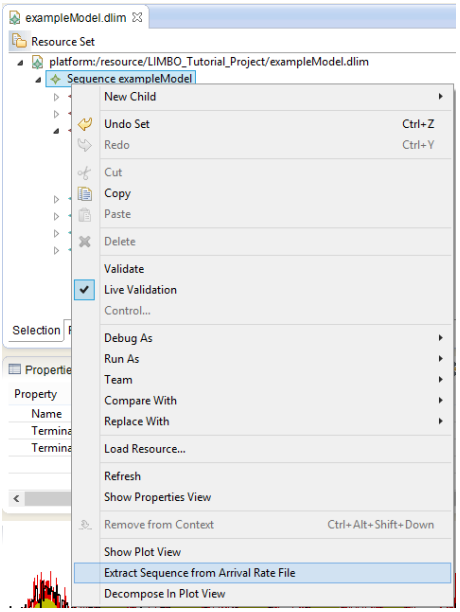

Figure 1.14: Extract Sequence from Arrival Rate Trace.

Set the downloaded trace as the **Arrival Rate File**, then select the **Simple Process Extractor** and click **OK**. The Periodic Process Extractor is explained in Section 1.5.1. Other extractors may appear, provided by third party plug-ins.

In the following dialog, set the **Seasonal Period** to **24** (the trace features hourly samples) and set the **Seasonal Periods per Trend** to **1** (This setting affects trend segment length, just as it did in the model creation wizard). Click **OK** (Fig. 1.15).

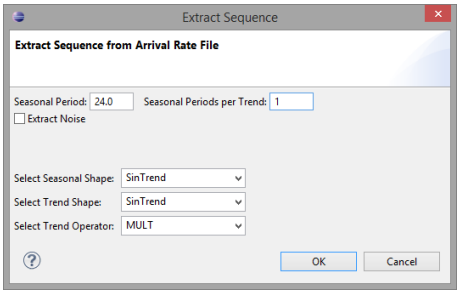

Figure 1.15: Extract Sequence from Arrival Rate Trace.

1.4.5 Comparing Model and Trace

There are two ways to compare the extracted model instance to the original trace:

In the Plot View: Right-click → **Toggle Arrival Rate File Plot** → select the Wikipedia trace → **OK**. You might want to also **Toggle Decomposition** again for better visibility. The Plot View now displays the arrival rates from the trace and the arrival rates of the model for comparison (Fig. 1.16).

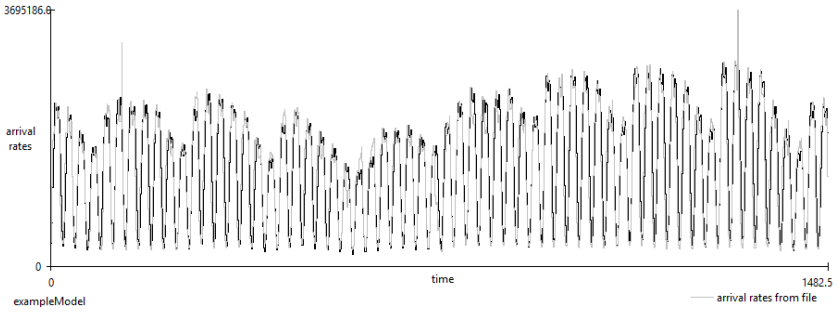

Figure 1.16: Plot View Comparison of Model and Trace.

Save the .dlim file (**ctrl+s**). In the Project Explorer Right-click on the .dlim file → **Calculate Difference to Arrival Rate File** → select the Wikipedia trace for the **Arrival Rate File** → **OK** (Fig. 1.17). A dialog with a number of difference metrics appears. A list of all absolute differences is also written to the Eclipse project's *diffs* folder.

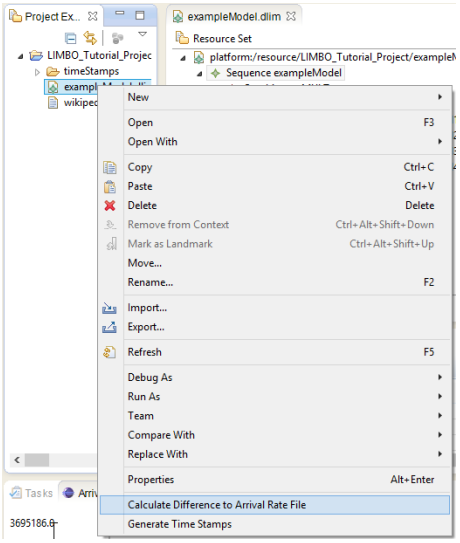

Figure 1.17: Calculate Difference between Model and Trace.

1.5 Additional Features

These additional features are not part of the tutorial, but warrant additional explanation.

1.5.1 Periodic Process Extractor

The periodic extractor is a more complex extractor, which assumes that trends are repeating. For this the periodic extractor takes trend-segment-lists, which repeat. While the process allows for trend lists of arbitrary length, the GUI only allows for lists with 2 trend segments.

These lists can be added by filling the two text-fields below the list view in the extractor's dialog and then clicking **Add**.

Common inputs are weekly repeating trend lists with a total duration of 7 seasonal periods (days) (e.g.: 3,4) or monthly / 4-week lists with a total duration of 28 days (e.g.: 14,14) (Fig. 1.18).

Sequences derived using the Periodic Process Extractor are usually less accurate than *Sequences* derived using the Simple Process Extractor. They can however extend infinitely since their trends repeat.

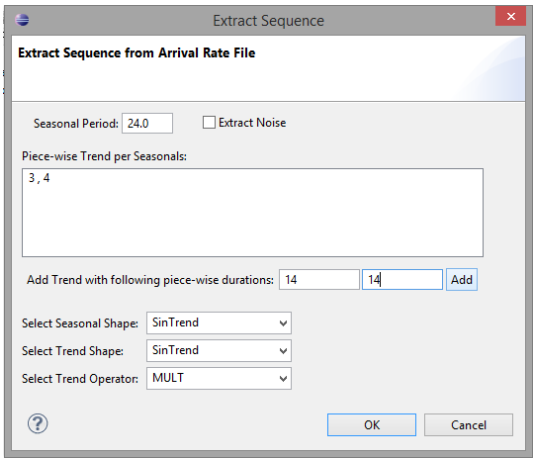

Figure 1.18: Periodic Process Extraction Dialog.

1.5.2 Difference Calculator

The difference calculator calculates the difference between an arrival rate trace file and a DLIM instance. In the Project Explorer Right-click on the .dlim file → **Calculate Difference to Arrival Rate File** → select the arrival rate trace for the **Arrival Rate File** → **OK**. A list of all absolute differences is also written to the Eclipse project's *diffs* folder.

Additionally the difference calculator displays its results in a dialog (Fig. 1.19). This dialog displays the absolute and relative median and mean differences, as well as a relative curve difference based on the Dynamic Time Warping (DTW) algorithm. The DTW difference takes into account that the arrival rate variations may contain accurate arrival rates, yet be offset by time. As a result it is usually smaller than the relative mean and median differences. It is useful for comparing different model instances on the basis of the same trace.

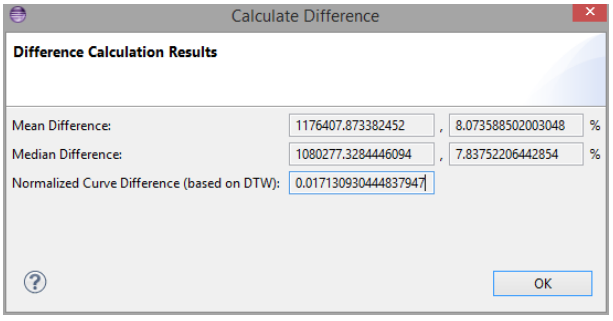

Figure 1.19: Results of a difference calculation.

Note: The difference calculator can only compare DLIM instances with traces containing tuples of time stamps and arrival rates. Running the difference calculator against pure time stamp lists results in an error. LIMBO does, however, include a feature to create

time stamp / arrival rate files from simple request time stamp lists. To do so, simply right click on your respective time stamp file and then select **Generate Arrival Rates from Time Stamps**.

1.6 Example Models

An Eclipse project with example Models can be downloaded from GitHub at:

`https://github.com/joakimkistowski/LIMBO/tree/master/DLIM_examples`