Translating Simulink Models to Modelica using the Nsp Platform
Jean-Philippe Chancelier, Sébastien Furic, Pierre Weis

To cite this version:
Jean-Philippe Chancelier, Sébastien Furic, Pierre Weis. Translating Simulink Models to Modelica using the Nsp Platform. 2019. hal-01948681v2

HAL Id: hal-01948681
https://hal.archives-ouvertes.fr/hal-01948681v2
Submitted on 21 Feb 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers. L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
Translating Simulink Models to Modelica using the Nsp Platform

Jean-Philippe Chancelier\textsuperscript{1} Sébastien Furic\textsuperscript{2} Pierre Weis\textsuperscript{2}

\textsuperscript{1}Université Paris-Est, CERMICS (ENPC), 77455 Marne-la-Vallée 2, France, jean-philippe.chancelier@enpc.fr
\textsuperscript{2} Inria Paris, 2 rue Simone Iff, 75589 Paris, France & Université Paris-Est, CERMICS (ENPC), 77455 Marne-la-Vallée 2, France {sebastien.furic,pierre.weis}@inria.fr

Abstract
We present a new Simulink (Simulink) to Modelica (Modelica) translation chain embedded into Nsp. Translated models can be edited (original Simulink diagrams are preserved through translation) and simulated. This translation chain makes use of the Simport tool, originally designed to translate Simulink models to Scicos models, and also relies on Modelica, i.e. Scicos’ Modelica companion compiler.

Using some examples, we demonstrate the effectiveness of the translation process and detail some technical aspects of it. This new Nsp feature extends Nsp’s simulation capabilities and makes it a reference platform for users looking for means to simulate Simulink models within a Modelica framework. Resulting Modelica code can even be exported to other Modelica compatible tools.

Keywords: Nsp; Simulink; Modelica

1 Introduction
Nsp (Nsp) is a Matlab-like numerical environment which can run the Scicos modeling environment, a Simulink-like block diagram editor and simulator.

From 2003 to 2008, in the course of funded projects SimPA and SimPA2, a Modelica compiler named Modelica has been developed allowing Scicos to handle genuine Modelica models. This integration of Modelica within Scicos has been the subject of several papers published at the Modelica conference (Nikoukhah and Najafi, 2008; Nikoukhah and Furic, 2009). The purpose of using Modelica is to serve as a high-level description language to extend Scicos expressiveness: Modelica allows users to compose “acausal” models where the original environment forced users to describe their models as block diagrams.

In this paper we focus on a new application of Modelica within Scicos under Nsp, that is as a target language for Simulink model translation.

Several Simulink to Modelica translation tools have already been proposed in the past, we mention in particular Mike Dempsey’s Simelica and AdvancedBlocks library (Dempsey, 2003) and Dirk Reusch’s Coselica initiative (Reusch). AdvancedBlocks was a fairly complete library of Modelica blocks which allowed users to use Modelica blocks as a one-to-one replacement for Simulink blocks. Up to our knowledge this work remains the most advanced effort in that direction. It is however no longer maintained. In the Scicos software environment, the Coselica library offers signal models to allow users to better exploit Modelica from within Scicos by proposing a large set of Modelica submodels in the same spirit as the standard Modelica library (MSL). Many Simulink-like blocks are also available in Coselica.

The approach presented here differs from Mike Dempsey’s and Dirk Reusch’s approaches in that translation of original blocks is not attempted on a one-to-one basis. Instead, we use a two steps translation process: the first step translates the Simulink model into an equivalent Scicos native model; the second step translates the Scicos native model to Modelica code.

To handle the initial Simulink to Scicos translation, we use an external tool named Simport: it translates a Simulink model by translating each block in the original Simulink model with one or several blocks of the Scicos native block library, so that original semantics is preserved with a high degree of confidence.

For the second step, we developed a set of Nsp special purpose compilation routines to translate Scicos blocks to genuine Modelica blocks. When a Scicos block has a direct Coselica equivalent, the compilation routine simply emits the corresponding Coselica block; when there is no Coselica equivalent, the compilation routine generates an entirely new block containing ad-hoc Modelica code to handle the Scicos block behavior. Using this compile-time Modelica code generation and the two steps translation process was the key ideas to fill the huge semantic gap between Simulink and Modelica.

We give in this paper a detailed description of this new translation chain hosted by the Nsp environment.

2 Involved Tools
As mentioned above, the translation chain relies on a combination of several tools. We give hereafter a short description of each of them.

2.1 Nsp, a Programming Environment for Numerical Applications
Nsp (Nsp) is a mature Matlab-like Scientific Software Package developed under the GPL license. Nsp features a high-level, safe imperative programming language with
automatic memory management. This language can be used interactively, giving users an easy access to efficient numerical routines; It can also be used as a more conventional programming language to extend Nsp’s capabilities.

Nsp contains internally a class system with simple inheritance and interface implementation. When used as an interactive computing environment, it comes with online help facilities and an easy access to GUI facilities and graphics.

A large set of libraries are available and it is moreover easy to implement new functionalities. External libraries can also be used: this requires writing some wrapper code (also called interface) to live in harmony with Nsp’s internal state. The interface mechanism can be either static or dynamic. By using dynamic functionalities one is able to build toolboxes.

Nsp shares many traits with other Matlab-like Scientific Softwares such as Matlab, Octave, ScilabGtk (ScilabGtk; Campbell et al., 2006), and also with scripting languages such as Python.

The main toolbox used in this work is Scicos that we describe now.

### 2.2 Scicos, a Block Diagram Modeler and Simulator

Scicos (Scicos) is a graphical dynamical system modeler and simulator originally developed in the Metalau project at INRIA, Paris-Rocquencourt center. With Scicos, users can create block diagrams to model and simulate the dynamics of hybrid dynamical systems and compile models into executable code. Scicos is used for signal processing, systems control, queueing systems, and to study physical and biological systems. Extensions allow generation of component-based modeling of electrical and hydraulic circuits using the Modelica language.

We consider in this paper the Scicos/Nsp version of Scicos maintained and developed at ENPC. Scicos/Nsp is a Nsp toolbox and runs in the Nsp environment. Having access to Nsp functions when designing simulation models is of great importance.

Scicos users often needs to use Nsp functions such as those dedicated to filter design for signal processing or controller design in the construction of simulation models. Nsp’s programming language can be used for batch processing of multiple simulation tasks, and more generally, models designed by Scicos can be used as functions in Nsp. Nsp’s graphical facilities can be used for post processing simulation results. But the integration of Scicos and Nsp goes beyond that. The Scicos editor is entirely written in Nsp’s language. This provides many advantages and was in particular of tremendous importance in the current work, indeed: Scicos model data structure is a Nsp structure and thus Scicos models can be systematically manipulated and build using Nsp scripts. We use this facility in two ways. First to obtain Scicos models from Simulink models, using the fact that the Simport converter produces a Nsp script whose execution in Nsp produces a Scicos model data structure. Second, using Nsp scripts we are able to convert, in a Scicos model data structure, some Scicos blocks to Modelica blocks.

In the conversion process from Simulink to Modelica, the scicos compiler/scheduler also plays a key role. It infers dimensions and types used in the Modelica blocks. This is quite an exciting feature since it gives the possibility to have Modelica blocks for which the associated Modelica model is not a fixed Modelica class but a specific one adapted to specific dimensions and types generated on the fly.

### 2.3 Modelicac, a Simple Yet Useful Modelica Compiler

Development of Modelicac started in 2003 as a joint work between Inria and TNI-Valiosys (now Dassault Systèmes) in the course of the SimPA (SIMulation pour le Procédé et l’Automatique) french funded project. The goal was to make Scicos compatible with a significant subset of the Modelica language in order for users to be able to describe complex hybrid models without having to resort to low-level block diagram descriptions. Indeed, building a block diagram from a physical model requires 1) performing a complete analysis of physical phenomena into play (to determine which elementary blocks to use in the diagram), and 2) determining how data flows between blocks (to connect elementary blocks together). On the other hand, Modelica tools considerably ease physical model construction by automatically analysing the overall structure of physical models described in a much more user-friendly way: familiar physical components (e.g. springs, transistors, hydraulic pumps, etc.) can be used to build models. Translation from this high-level description to low-level data flow is performed automatically in a quite satisfactory way, which frees users from a painful work. Moreover, even slight modifications of physical models may require considerable changes in corresponding block-diagram descriptions; this is not the case with a high-level description.

In its initial version, Modelicac essentially focussed on the “continuous part” of hybrid models. This mainly comprises differential equations and event-trigerring mechanisms (e.g., “when equations”). Difference equations were however also be described, although with many restrictions, because the idea was to discourage users from writing discrete equations in Modelica. Indeed, Scicos is primarily a hybrid modelling environment and, in particular, it handles discrete, event-triggered changes, much more robustly than Modelica because of its synchronous roots.

In the course of the SimPA project, the Scicos editor has been extended to enable graphical handling of Modelica, native Scicos, as well as hybrid Modelica-Scicos blocks in the same design (see Figure 1).

This combination of synchronous and Modelica-based features offered enough modelling expressiveness to enable useful libraries to be developed. Coselica is one of these libraries, and is one of the ingredients of our
Simulink to Modelica translation chain.

In 2005, the funded project SimPA2 started, having as objective the enhancement of the original Modelica compiler. Among others, support of multiple-file Modelica libraries and interactive initialization of complex hybrid systems have been added.

As a result, the new Modelica compiler was able to compete with industrial compilers (it even ranked number two in terms of performance on an industrial thermohydraulic benchmark proposed by EDF in 2009).

Today, the Scicos toolbox with its Modelica-compatible extension is freely available under several environments including Scilab, ScicosLab and Nsp.

### 2.4 Simport, a Simulink Model Importer for Scicos

#### 2.4.1 Capabilities

The Simport (Chancelier et al., 2016, 2015) development started in 2007 at Inria: it has now turned into a comprehensive Simulink import assistant for the Scicos and Altair Activate block system models: Simport reads a textual representation of a Simulink model (MDL or SLX file format) and generates the corresponding equivalent Scicos model.

Based on compilation techniques, Simport is a fast and reliable translator from Simulink models to Scicos or Altair Activate models.

Simport is a free software distributed with Nsp Scicos (Scicos) and Activate (Altair Activate).

#### 2.4.2 Capabilities

Simport aims at preserving the original Simulink model semantics: simport performs passes of semantic analysis to explicit the Simulink model meaning and translate it into an equivalent Scicos model.

In any case, the resulting Scicos model preserves the model hierarchy and diagram topology, and the visual aspects of the original model.

Simport also supports both the MDL and SLX formats as input for Simulink models.

#### 2.4.3 Simulink block translation

Simport maps Simulink bloks to Scicos blocks using the block translation library. More precisely, each Simulink source block is translated either into

- a single basic block, if there exists an equivalent Scicos block,
- a super-block that implements the Simulink block via a combination of Scicos blocks,
- an empty super-block for user completion, if the Simulink block translation is unsupported

The Simport translation library covers a large subset of Simulink basic blocks, in particular the so-called action blocks.

#### 2.4.4 Simport generated code

The Simport back-end translates explicit semantics of Simulink models to concrete code of the Scicos host language (Nsp or Oml). In addition, the concrete code provides the definition of simulation parameters and embeds various outputs to the host language (e.g. Matlab supporting M-files).

#### 2.4.5 Example

Given the Simulink model described in Figure 2 and saved as file `model.mdl`.

We translate it into Nsp using the command `simport -tl nsp model.mdl`. We now get file `model.nsp` whose execution in Nsp produce build the Scicos model displayed in Figure 3.

#### 2.4.6 Limitations

Simport indeed supports a large subset of Simulink basic blocks, but exotic blocks from specific Simulink libraries cannot be translated since they have no Scicos equivalent;
in such a case, Simport generates an empty Scicos super block to incorporate the mandatory hand written Simulink block translation.

3 Translation from Simulink to Modelica

The translation from Simulink to Modelica is implemented as a two-step process. First, as already described, using Simport, we translate a Simulink model into a Scicos model. Second, using Nsp scripts we convert the Scicos model into an hybrid Modelica-Scicos model. Conversion is obtained by 1) translation of Scicos blocks to Modelica blocks, and 2) addition in the model of converters along the links which connect Scicos Blocks to Modelica-Scicos blocks. The hybrid Modelica-Scicos models can be edited and simulated in Scicos editor; thus, even if during the translation process we cannot obtain a full Modelica model\(^1\), the resulting hybrid model may still be used for simulation because users have the possibility to complete untranslated parts thanks to the Scicos editor.

Figure 4 is a Scicos model simulating the Lorenz dynamical system. The same model after conversion to Modelica is shown in Figure 5. As it can be seen in Figure 5 the Scopes are not translated to Modelica blocks and converters from Modelica signals to Scicos signals are inserted in the links connected to the entry ports of scopes.

When converters are available, Scicos blocks are replaced by Modelica blocks as a one-to-one process. We have developed a specific library of Modelica blocks to ease the replacement. For example Scicos integrator blocks are replaced by MB_Integral Modelica blocks. For some translation we rely on the already available library Coselica (Reusch), but for many blocks a direct Coselica translation fails because of size lim-

\(^{1}\)In case some blocks are unknown to Simport. Indeed, Simulink blocks are black boxes, so Simport cannot translate blocks or combinations of blocks that are not already described in its translation tables.
iterations of Coselica blocks. For example the Coselica
Integrator is limited to 1-dimensional signals while
the Scicos INTEGRAL_m block may have n-dimensional
entries. One way to encompass that difficulty is to gen-
erate super blocks for enabling n-dimensional block oper-
ations from 1-dimensional basic blocks (See Figure 7
for an example with adder). We have chosen this approach
for the converter blocks (See Figure 6) as explained be-
low, but we also implemented specific blocks to deal with
n-dimensional signals. For example, the MB_Integral
block is a special purpose Modelica-Scicos block which
produces at compile time a new Modelica model for each
instance of the block in a specific model. As an example,
in Figure 5 each MB_Integral Modelica block inte-
grate a 4-dimensional variable without saturation and thus
the generated code will be given by

```model integral2
    parameter Real xinit[4,1] = {{ 20 },{ 19.9900-semibold space},{ 20.0100 },}{ 20.0110 }; RealInput u[4]; RealOutput y[4](signal(start=xinit[:,1]));
equation
    der(y[1].signal) = u[1].signal;
    der(y[2].signal) = u[2].signal;
    der(y[3].signal) = u[3].signal;
    der(y[4].signal) = u[4].signal;
end integral2;
```

Most of the one-to-one block conversion follows the same
mechanism. Building a library of Modelica-Scicos blocks
is an on-going work and for the time being it only contains
about 20 blocks. Indeed, this Library can also be used to
directly build models in the Scicos editor, it complements
the set of Modelica block available in Scicos giving access
to Modelica counterpart of known Scicos blocks.

The one-to-one block conversion is in fact also a multi-
step process. We proceed as follows.

First block-to-block conversions are performed but con-
verted Modelica-Scicos blocks are not fully usable because
they lack local information (for example the final matrix
sizes are unknown at first step). Notice that this first step
requires Nsp evaluation of block parameters since they
may be used to infer types and dimensions. For example
the sizes of a Gain block parameter gives the input/output
port sizes of the block, except when the parameter size if
1. But in order to obtain the sizes of a given Gain block
parameter we need to evaluate Nsp expressions, since pa-
rameters can be given through context (produced by Sim-
port from Matlab companion files).

In a second step, links are modified and converters are
inserted where appropriate. Notice however that convert-
ers sizes are also unknown.

In a third step, sizes and types are obtained by call-
ing the Scicos model compiler. However, since the Sci-
cos model compiler only infers types and dimension for
Scicos blocks this step requires a hidden conversion of the
hybrid Modelica-Scicos model into a pure Scicos model
before trying to infer sizes and types. When sizes and
types are inferred for a Modelica-Scicos block, its internal
Modelica code can be generated. The code is thus consis-
tent with respect to sizes, types and parameters.
Figure 8. A mixed Scicos-Modelica model of a RLC circuit

and sizes is of utmost importance and it partially relies on
Nsp block parameter and context expression evaluation.
This is mostly why the conversion cannot completely be
performed by Simport. Indeed, inferring types and sizes
could have been implemented directly in Simport, if evaluation
of Matlab expression were not required in the pro-
cess.

3.1 Translation from Modelica to C

Modelica source code is translated to C thanks to the Mod-
elicac compiler. The idea is as follow. Once the model is
being run by the user, Scicos gathers all the blocks whose
execution semantics is described by means of Modelica
description and instantiates, C-based Scicos blocks. It starts by resolving the
names appearing in the Modelica description and instanti-
ates required classes (found in libraries) to form the set of
equations governing the dynamics of the Modelica part
of the model. The following listing illustrates what such a description looks
like. It contains the Modelica description generated by
Scicos for the model of Figure 8:

```model RLC_circuit_test_im
parameter Real VA_VsourceAC_(fixed=false) = 2.000000e+00 "VA_VsourceAC_";
parameter Real f_VsourceAC_(fixed=false) = 1.000000e+00 "f_VsourceAC_";
parameter Real R_Resistor_(fixed=false) = 2.000000e-01 "R_Resistor_";
parameter Real L_Inductor_(fixed=false) = 1.000000e-04 "L_Inductor_";
parameter Real C_Capacitor_(fixed=false) = 1.000000e-01 "C_Capacitor_";
parameter Real v_Capacitor_(fixed=false) = 0.000000e+00 "v_Capacitor_";

VsourceAC VsourceAC_(VA=VA_VsourceAC_,
                f=f_VsourceAC_);
Resistor Resistor_(R=R_Resistor_);
Inductor Inductor_(L=L_Inductor_,
                        v=start=v_Capacitor_);
Capacitor Capacitor_(C=C_Capacitor_,
                        v=VoltageSensor_.v);
CurrentSensor CurrentSensor_(
                           Ground_,
                           VoltageSensor_.v);
OutPutPort OutPutPort_1;
OutPutPort OutPutPort_;
ground Ground_;
VoltageSensor VoltageSensor_;

end RLC_circuit_test_im;
```

Modelica programs generated by Scicos contain five (pos-
sibly empty) sections declaring respectively:

- the parameters of the model,
- the components appearing in the model (i.e. Model-
ica “blocks” used to build the model),
- the connectors to and from the Scicos world (de-
clared as InPutPorts and OutPutPorts),
- the connection equations (corresponding to links
between components of the model, introduced by
means of the connect keyword), and
- the correspondence between some Scicos ports and
some Modelica connectors used to exchange inform-
ation between both worlds (introduced by means of
an equal sign).

From such Modelica programs Modelicac generates na-
tive, C-based Scicos blocks. It starts by resolving the
names appearing in the Modelica description and instanti-
ates required classes (found in libraries) to form the set of
equations governing the dynamics of the Modelica part
of the model. It then flattens the structure of the Modelica
model, simplifies equations, and generates C code. The
following listing is the result of calling Modelicac with
previous Modelica code:

```void RLC_circuit_test_im(
    scicos_block *block,
    int flag)
{
    int *ipar = GetIparPtrs(block);
    double *rpar = GetRparPtrs(block);
    double *g = GetGPtrs(block);
    double *alpha = NULL;
    double *beta = NULL;
    double *u = GetInPtrs(block);
    double *v = GetOutPtrs(block);
    int *xprop = GetXpropPtrs(block);
    int *jroot = GetJrootPtrs(block);
    int *nevprt = GetNevIn(block);
    int *mode = GetModePtrs(block);
    /* OutPutPort_1.vo */
    /* OutPutPort_.vo */
    /* OutPutPort_1.vo */
    double v0;

    if (flag == 0) {
        res[0] = x[1]*x[0] +
                 x[2] + GetRealOparPtrs(block,3) +
                 sin(6.28318530718*
                     GetScicosTime(block)*
                     GetRealOparPtrs(block,6)) *
                 GetRealOparPtrs(block,2)
                + GetRealOparPtrs(block,1)
                + GetRealOparPtrs(block,4); }
             x[1] +
             x[0] +
             x[2] +
             x[0] +
             x[1] +
             x[2] +
             x[0];
    if (flag == 1) {
        if (areNodesFixed(block)) {
            y[0][0] = x[0]; /* OutPutPort_.vo */
            y[1][0] = x[1]; /* OutPutPort_1.vo */
        } else {
            y[0][0] = x[0]; /* OutPutPort_.vo */
            y[1][0] = x[1]; /* OutPutPort_1.vo */
        }
    } else if (flag == 2 && nevprt < 0) {
    } else if (flag == 4) {
```
Several enhancements can be made to this preliminary work. The most significant enhancement would probably consists in enriching the Scicos to Modelica translation table, to allow more Simulink models to be translated automatically.

6 Acknowledgements

We would like to thank Ramine Nikoukhah from Altair for his considerable help in the design and implementation of the tools we used, in particular Scicos of course, but also Modelica and Simport.

References


