Latest advances in EcosimPro Simulation Tool

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www.ecosimpro.com
History of EcosimPro

- The project started in 1989 with funds from the European Space Agency (ESA) to simulate Environmental Control and Life Support Systems for manned spacecraft (Hermes y Columbus).
- Since then, it has been used in many other fields: fluids, chemical, control, electrical, propulsion, etc.
- Version 3.0 in December 1999 for PC-Windows.

EcosimPro OVERVIEW

What is EcosimPro?

- EcosimPro is a mathematical tool for modeling and simulating continuous and discrete systems.
- It represents the state-of-the-art in continuous non-causal simulation.

Applications of EcosimPro

- EcosimPro is applicable to any problem domain which can be represented by Differential-Algebraic Equations (DAE) and Discrete Events.
- For example: chemical, thermal, control, hydraulic, electrical, propulsion etc.
EcosimPro Capabilities (I)

♦ Symbolic handling of equations and numeric solvers for differential-algebraic equations and discrete events
♦ Object-oriented modeling language with the latest capabilities such as multiple inheritance, assertions, virtual equations, etc
♦ Calculation of transient and steady states

EcosimPro Capabilities (II)

♦ Visual development environment (similar to Microsoft Visual Studio)
♦ Graphical modeling tool based on dragging and dropping symbols from a palette
♦ Creation of reusable and non-causal components
♦ Very powerful equation solvers (nonlinear and differential-algebraic equation systems)
♦ Optimized to work with large models (thousands of equations)
EcosimPro Capabilities (III)

♦ Math wizards to help define boundary conditions, solve algebraic loops and high index math problems
♦ C++ and OCX (COM) code generation
♦ Results are easily exported to Excel and Word

Reuse of Models

♦ Non-causal modeling implies that at the time of modeling there is no a priori knowledge of the known and unknown variables. The user only writes the laws governing the phenomenon (e.g. \( v = R \cdot i \) or \( i = v/R \) or \( 0 = v - R \cdot i \))
♦ The modeling is therefore very universal and reusable, causality is defined at the end of the process
♦ EcosimPro allows creation of reusable component libraries
♦ Until now, the simulation analyst was 80% programmer and 20% modeler. The situation is reversed with EcosimPro
EcosimPro (non-casual) versus Simulink (causal)

In Simulink, the first step is to write the equations by hand, then sort them with their causality and finally draw them.

\[ i_C = \frac{(U - U_C)}{R1} \]
\[ U_L = U - i_L \times R2 \]
\[ U'_C = \frac{i_C}{C} \]
\[ i'_L = \frac{U_L}{L} \]

EcosimPro versus Simulink

In Simulink the modeler “draws” the equations but not the system to be modeled.
In EcosimPro the modeler first creates the basic components and then reuses them:

```plaintext
COMPONENT Capacitor IS_A Twopins
    DATA
        REAL C = 1e-6 "Capacitance (Farads)"
    CONTINUOUS
        v' = i / C -- Capacitor law
END COMPONENT
```

Electrical DIAGRAM

EcosimPro DIAGRAM
Object-Oriented Dynamic Modeling

Advantages:

♦ 1- It allows non-causal modeling
♦ 2- It is easier to reuse
♦ 3- It is easier to maintain and extend (compare with old FORTRAN programs).
♦ 4- At last the modeler models dynamic systems, it is not only a low level programmer!

EL (EcosimPro Language): The Modeling Language

♦ Very intuitive syntax
♦ Object oriented (multiple inheritance, aggregation, etc)
♦ Enumeration type data
♦ Multidimensional arrays
♦ 1D, 2D and 3D tables
♦ Connection with FORTRAN, C and C++ functions
♦ Use of assertions to check consistence at all times
♦ Representation of DAEs, ODEs and discrete events
♦ Simple and intuitive concept of components library
## EL: Example of Point Mass Movement

```plaintext
COMPONENT point

DATA

REAL m = 1 "mass (Kg)"

DECLS

REAL F "force (Newton)"
REAL x "space (m)"

CONTINUOUS

F = m * x'' -- Newton's law

END COMPONENT
```

## Heater Component of ECLSS Library

```plaintext
COMPONENT Heater IS_A HeatStorageChannel

PORTS

IN analog_signal s_pow "Power signal"

DATA

REAL dp_ref "Reference pressure loss (Pa)"
REAL w_ref "Reference mass flow for pressure loss data (kg/s)"
REAL rho_ref "Reference density for pressure loss data (kg/m^3)"
REAL dp_lam = 10 "Pressure drop for laminar flow (Pa)"

DISCRETE

ASSERT (abs(f_out.rho - f_in.rho) / f_in.rho < 0.1) WARNING "Density change too high for uncompressible flow formulation"

CONTINUOUS

-- Momentum

f_in.w = w_ref * s_sqrt((f_in.p - f_out.p) * f_in.rho / rho_ref) -- Energy equations

q = s_pow.signal

END COMPONENT
```
New features in Version 3.1 (I)

♦ Sparse solver for handling problems with thousand of state variables. There are disciplines where the number of state variables is very large (thermal, chemical, etc.), previous version (3.0) had a limitation about 350 state variables. New version can handle models with thousands of state variables.

♦ Implemented a classical four order Runge-Kutta solver for simple applications (very fast!).

♦ Automatic generation of an ActiveX DLL to connect any EcosimPro model to Microsoft applications. Typically the user can run the simulations from Excel. He can create quickly a macro to associate an EcosimPro model to an Excel sheet.

New features in Version 3.1 (II)

♦ Faster and more reliable interaction with graphical tool SmartSketch.

♦ New object editors in SmartSketch. They are more simple to use. The units and description of data are displayed now.

♦ Improvement in the automatic “update” feature (makefile in UNIX).

♦ Improved editors for 2D and 3D tables

♦ Clever handling of external libraries (eg FORTRAN)

♦ Better suggestions from the mathematical wizards

♦ More intelligence detecting equivalent variables in systems
New features in Version 3.1 (III)

♦ The wizard for high index able to solve more complex problems.
♦ New EXPAND_BLOCK statement for generating in a single block many equations (like EXPAND for a group of equations)
♦ More than 100 small bugs solved
♦ Many small improvements suggested by users implemented
♦ Saving of graphics configuration now saves all changes

New features in Version 3.1 (IV)

♦ Improved log info when no convergence in models occurs
♦ Better control of convergence for steady states
♦ Access to all Ecosim Manuals from the GUI
♦ New plots versus TIME and any other variable
♦ New thermometer gauge for experiments
♦ Simplified the regular expressions mechanism for reporting variables
EcosimPro Libraries

- ECLSS Library
- Thermal Library
- Control Library

Other Libraries:
- Propulsion Library
- Pipe Network Library
- Electrical Library
- Heat Balance of Power Plants
Aerospace Organisations Using EcosimPro (Oct-2000)

- ESA-ESTEC (Holland)
- NASA Marshall Space Flight Center (USA) is using EcosimPro for all new ECLSS models for the ISS
- Astrium, Germany (ECLSS and Propulsion)
- ALENIA, Italy (ECLSS)
- SNECMA, France (Gas Turbines)
- Hurel Dubois, France (Thermal and Propulsion)
- ITP, Spain (Control and Propulsion)
- Evaluating now: Rolls Royce (Fluids and Hydraulics), EADS Spain (Thermal), Boeing (ECLSS), Lockheed Martin (ECLSS), British Aerospace

Conclusions

- EcosimPro is a flexible tool, that can be adapted to multiple fields.
- It supports physical modelling (the model looks like the actual system)
- The user can create new components and new Libraries (he does not depend on the software developer).
- New version 3.1 implements many new capabilities requested by users
- New versions will include optimisation, parameter estimations, modelling of some PDE’s, etc.
More Information...

♦ New web from September 2000 with full information about existing libraries, applications, support, resellers, etc.

WEB:    www.ecosimpro.com
E-Mail:  ecosim@empre.es

♦ It exists an Internet group to be informed about modeling issues, new releases, etc. It is free to join the group. Visit the page www.coollist.com and join the group “ecosim-group”.

♦ Free evaluation version valid for 30 days

EcosimPro COURSES

♦ Special courses for ECLSS, Thermal and Propulsion engineers.

♦ The course takes three days

♦ New courses are organized every four-five months. Updated info in our web page.

♦ Next course by Jan-Feb-2001 (ESTEC or Madrid?).

♦ Price: around 450 EUROS

♦ Contact P. Cobas (pce@empre.es) or Olivier Pin (Olivier.Pin@esa.int)
PRICES

♦ 1 permanent license: 2500 USD

♦ 1 University Depart. license: 1500 USD

♦ 1 Limited Edition(60 equations): 240 USD