Software Modelling

Business and IT challenge

Time Dependent Probabilistic Safety Assessment (TDPSA), is a system being developed by AEA Technology (AEAT), on behalf of NIREX Ltd, with the assistance of Tessella. It is designed to model the possible environmental impact of the disposal of radioactive waste in underground repositories.

Uncertainty in the final demands on the software system required a high degree of flexibility and so an object-oriented (OO) approach was used. This meant not only writing the software in OO, C++ and Java, but also designing the framework of the system to allow its component modules to be "plugged" together by the user, as objects within the graphical user interface (GUI).

TDPSA Models

To simulate underground waste disposal over long timescales requires the modelling of a large number of factors. These include; modelling how contaminants could dissolve in water, how water migrates underground through layers of rock and may reach surface water bodies and soils, leading to possible contamination of plant and animal life. With a large number of factors to take into consideration, it is impractical to have every factor put into one, highly complex model. The solution adopted by AEAT was to construct a separate, smaller model for each of the factors that need to be studied. Related models can then be connected together so that they form a model network. This approach has three main benefits:

- When a model is developed, the writer need only have expertise in the area in question. An expert on the mathematics of groundwater flow can construct a model to simulate just this, without concern for how contaminants dissolve in the water he is modelling.
- If the internal structure of the model is changed, perhaps for efficiency reasons, then the other models in the network do not need to be altered.
- When a further aspect of the modelled environment is identified, a new model can be written and added

to the model network without changing the overall framework.

Models are connected together when an interchange of information between them can occur, often because one model will affect the behaviour of another. The models may also contain parameters, which can be defined as algebraic expressions involving constants, probability functions and other parameters, so they are more than just simple variables. In fact, TDPSA contains a compiler to turn these expressions into data that can be used by the models.

Solving the Network

The user is presented with a palette of available models which may be added to the current network. Each of the models appears as a box and their "ports" (the inputs and outputs from the models), can be connected together by simply dragging a line between them.

Where the TDPSA environment differs from other packages is that when models are connected together, they can be considered as one large model. Since each model defines a set of differential and algebraic equations, the network yields the equation systems that would have been generated by a small number of large monolithic models. The solver module in TDPSA can then be applied to the systems of equations, given by these "super-models", to simulate the repository site. In other packages, each model would only be able to pass data to its connected models and would have to be completely self-contained. There would be no way to generate systems of equations for groups of models within the network. For example, two models each defining a simple linear equation; x=y+3 and 2y=x+2. If these models are connected together by two ports linking their respective x and y variables, then the system can be solved, giving x=8 and y=5. Yet these equations cannot be solved separately, so the traditional data flow method could not be used.

Persistent Storage

Once a model network has been set up, it is necessary to be able to save it for later retrieval. The data generated by the system also needs to be archived to allow it to be analyzed later. This is done by using an object-oriented database system (OODBS), which allows whole objects, (rather than the usual simple numeric and text data), to be stored and retrieved by the software. Another feature of TDPSA is that it stores information about the models in the network as smaller "description objects" in the database. This means that if a model contains 100 floating-point numbers, then this fact is stored, rather than the 100 numbers themselves. When a network of models is retrieved from the database, a "realization" (i.e. the actual network of models), is generated from the description before a model solving run commences. The results from this run are then stored in the database ready for analysis.

Other Possible Application Areas

Any complex system that can be described in terms of differential and algebraic equations, and which naturally breaks down into a series of connected sub-models, would be amenable to this approach. As TDPSA is designed to model a system over time and perform probabilistic calculations, in theory, this approach could be used for modelling anything from the performance of an internal combustion engine to the behaviour of the economy.

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