MODELLING-Pitfalls of modelling

One of the main advantages of using simulation during the design process is its flexibility. Changing parameters to see their effect is often just a case of changing a numerical value and re-running the simulation. The downside is that it is very easy to misuse such flexibility, and it is easy to run a simulation model that is physically impossible to achieve or makes little sense when compared to the real system being modelled. It is also very easy to fall into the trap of trusting the output of a model without question, when a model is only as good as the person who created the model and entered its parameters. In short, it is possible that simulation is not modelling what you think it is and although the model may appear to be functioning correctly, without numerical error, the results can still be incorrect or inappropriate for a multitude of other reasons.

Conversely, a model may give results that are perfectly correct, but may have been 'over-engineered' in a sense that too much detail has been entered into the model. This is undesirable as increased model complexity means increased model run time and/or memory usage. We categorise such discrepancies as errors in model design.

As the purpose of simulation is usually to predict the behaviour of a design or system before construction, it is imperative that the results generated by the simulation closely agree with those of the actual device or system. Such confidence in the simulation output can only be gained by comparing the generated results to experimental results obtained from the device or system being modelled. This process is often termed validation.

How closely the simulation should match the experimental results will depend on the accuracy required, though a typical accepted discrepancy between experiment and simulation is in the region of 5%. In some cases it is only necessary for close agreement at certain points in the simulation,

When validating a simulation, it is important to start with a simple experimental set-up that can easily be replicated in the simulation. This way, if the simulation and experimental results do not initially agree, it is much easier to determine why.

Once a simulation model has been fully and successfully validated, it can then be used to predict the behaviour of a real device as many times as required. However, should any of the model parameters change drastically it may be necessary to re-validate the simulation.

To be confident in a simulation, it is usually necessary to perform two or more sets of different validations, just to be completely sure that the simulation agrees in several different cases. For example, in a PCB thermal model, it may be appropriate to validate against several different component sizes within the same PCB, or compare results for three different ambient temperatures etc.

An important skill in modelling is to be able to identify the source of any discrepancies or errors within a model, whether they are numerical errors, or errors in the model design.

Sources of error

The reasons why the results generated by a simulation and those obtained through experiment may not agree can be broken down into four categories.

- Human error. If the values of any of the simulation parameters have not been correctly entered into the simulation tool or program, then the simulation is not modelling what you think it's modelling! This can only be eliminated by carefully re-checking any value entries.

- Mismatch in physical layout. Care must be taken to ensure that the simulation model and the experimental set-up are physically the same. This is particularly important in terms of boundary conditions. In a simulation model of a board assembly, for example, the simulation may have the assembly surrounded by an air boundary such as a chassis, whilst the experimental values for comparison are based on a bare assembly placed on a lab bench, with airflow only from above. Such differences can cause a mismatch in results that could be interpreted as an incorrect parameter value.

- Material parameter mismatch. How do you know that the material parameters that have been entered accurately describe the materials in the real system or device? Unless it is possible to measure the parameters, which in many cases is very difficult, there is no option but to rely on values found in literature. In some cases, because of the variability of materials, these values can be inaccurate. The key to resolving such issues is to identify those parameters that are most likely to be inaccurate and vary these slightly to see if the results move closer or further away from the experimental ones.
- Discretisation error. Another possible source of error derives from the incorrect assignment of values for the parameter intervals. Errors can be caused if any of these is too large, in particular if Δt is too large, as this can

cause instability. Problems caused by instability are usually easy to spot as the results are often nonsensical.

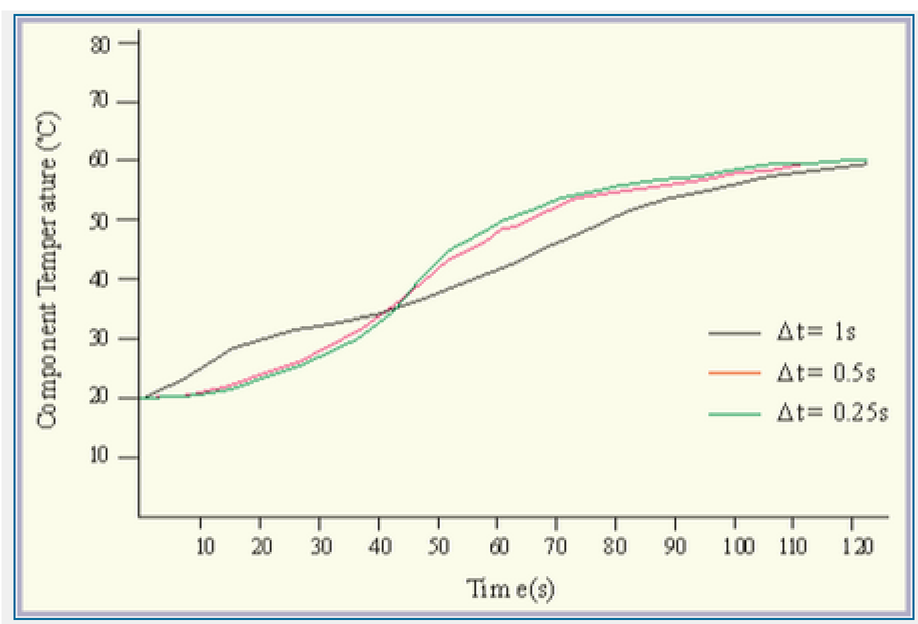
The type and amount of error depends heavily on the numerical method used in the modelling software. Some, such as the Finite Difference Time Domain (FDTD) method, become unstable when the values of the intervals are beyond a specific stability criteria, producing results that increase exponentially.

As well as instability, discretisation can also cause transient and or steady-state errors. With transient errors, the results bear no relation to anything that could happen in the real system, but steady-state errors are not so easy to spot.

Problems with model discretisation can be isolated from other sources of error by performing what is termed 'model convergence'. This involves running the same model several times but using different values of Dt and/or spatial values Dx, Dy, and Dz, and comparing the results generated in each case. For example, the initial value of Dt in a thermal model may be 1s. To check for any transient error we could re-run the model with a smaller value of Dt of 0.5s and compare the results generated. If the results agree sufficiently closely (say 5%), then the model is considered to have converged, and one can be confident that no significant transient error is present. Figure 1 shows a set of possible temperature convergence curves in a thermal model showing the temperature of an electronic component against time, using three different numerical time steps of Dt = 1, 0.5 and 0.25s.

Figure 1: Set of convergence curves

Set of convergence curves



The curves in Figure 1 suggest that the initial value of Dt = 1s was too large, because when the same model is re-run with a value of Dt = 0.5s the component temperature curve is significantly different. Moving to a smaller value of 0.25s makes only a small difference, hence we know that a Dt value of 0.5s only produces a small amount of transient error. The same kind of procedure can be used to isolate discretisation errors due to the values of Dx, Dy and Dz, but the convergence curves would be plotted against spatial position, rather than against time.

Author: Martin Tarr

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