Simulation Based Optimisation

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Modelling and simulation is of crucial importance for system design and optimisation. In aircraft, simulation has been strong in the area of flight dynamics and control. Modelling and simulation of the hydraulic systems also has a long tradition. The rapid increase in computational power has now come to a point where complete modelling and simulation of the sub systems in an aircraft is possible and also to use such a model as a basis for system optimisation.

There are several levels of design from requirement analysis and system architecture down to detail design. There is a clear danger that systems engineering activities are performed only at the top level of a design. In order to have an impact on the product development process it must, however, permeate all levels of the design in such a way that a holistic view is maintained through all stages of the design. This can be achieved if all design teams can work towards a common system model where the subsystem designs can be tested in an environment where the interaction with other sub-system and the whole aircraft can be studied.

Using the HOPSAN package (developed at Linköping University, Department of mechanical engineering) an actuation system control surfaces can be simulated using a flight dynamics model of the aircraft coupled to a model of the actuation system. In this way the system can be optimised for certain flight condition by "test flying" the system. The distributed modelling approach used, makes it possible to simulate this system much faster than real time on a 650 MHz PC. This means that even system optimisation can be performed in reasonable time.

An aircraft can to some extent be regarded as a heterogeneous system in that different parts eg wing, tail, propulsion etc are regarded as separate components with interaction. It also contains heterogeneous subsystems in different disciplines such as the hydraulic, electrical and fuel system. The engines can also be treated as such. This means that the aircraft model can be built in a more or less modular fashion.

A considerable effort has been made to develop methods suitable for simulation of systems. This means for example that it is possible to model basic aircraft systems, such as hydraulic system, air system and fuel system, much more efficiently than before, and that a lot of systems can even be simulated in real time. These models can also be coupled to models of flight dynamics, propulsion and flight control, to produce a more complete aircraft system model. Such a model can be used already in preliminary design, thus allowing the preliminary subsystem designs to be designed concurrently with the aircraft layout.

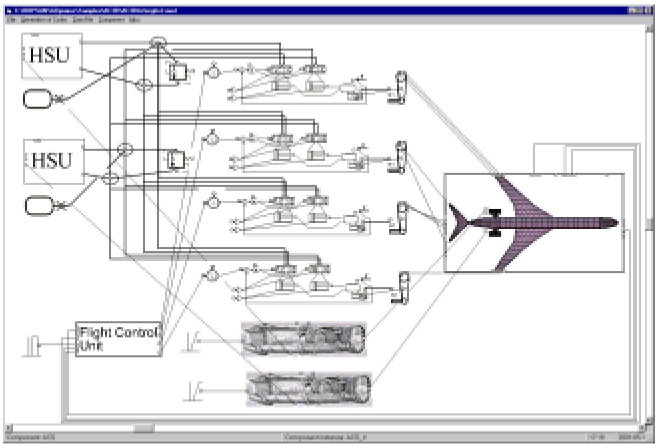

Figure 1. Simulation model with flight dynamics mode, actuator system, propulsion and flight control unit for the HOPSAN

Optimisation

If a simulation model is defined it is possible to use optimisation based on simulation. Using this method the system is simulated using a set of input signal sequences. The objective function could be to minimize the error in a certain node or nodes compared to a reference trajectory. Although this method may sound very time consuming it has some attractive features. Perhaps the most important is that it is possible also to include dynamic properties that can be optimised

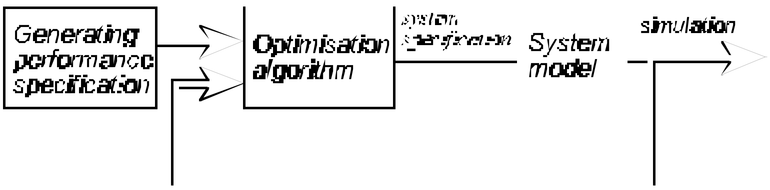

Figure 2. Optimisation based on simulation.

Tools-requirements

In order to handle modelling and simulation of large systems here are a range of requirements that need to be fulfilled:

- Object-oriented, to handle complexity in modelling
- Tool independent, modelling language to ensure longevity of the models.
- Database-technology to handle complexity in simulation data (and modelling).
- Distributed modelling for robustness and linear scaling properties
- Co-simulation capability, for flexibility

If simulation based optimisation is to be used there are also other considerations:

- Very strong emphasis on simulation speed.
- Deterministic simulation times are highly desirable.

Some simulation runs done in optimisation can result in very strange sets of parameters as the parameter space is searched for the optimum solution. This can result in system that are highly dynamic which can result in very long simulation runs if automatic variable time steps are used in the simulation. Therefore methods using fixed time step are desirable. The time step may, however, be different in different subsystems instead.

These requirements has resulted in the following strategy that is adopted for the development of the HOPSAN package:

- Modelling on a detailed equation level using a symbolic math package to generate implementation
- The distributed modeling approach for partitioning of systems
- Different time step for different parts of the model

XML

There is also ongoing development with the prime objective to introduce a model centric architecture as opposed to the traditional tool-centric architecture. The extensible markup language XML is a prime candidate for defining tools independent model-structures. The XML technology is characterized by the fact that is made to be transformable. There are transformation tools XSLT that can convert a XML-document based on one schema (format) into another a document based on another schema, or into any other arbitrary textual form. XML allows for a highly modular approach of system development, since the different tools can interact with the same model. XML also has a great potential beyond simulation. Defining an XML-schema for aircraft (eg AircraftML) could be a very useful thing since it would allow easy transfer of aircraft definitions between different tools.