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Modeling Analysis and Control of Dynamic Systems
<modeling.ps, pdf>
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Some observations about the use of engineering models

Models can be defined as abstractions. Mathematical models, including those in graphical form, are often called mathematical models - that is symbolic abstractions in the form of mathematical relations.

In general models there are two types of models: 1) Descriptive models and 2) Predictive models. A descriptive model describes observed or recorded behavior. A predictive model predicts behavior of a system not previously observed. (Perhaps the real system has not been realized in hardware or the real system has never been tested under the conditions the model is being used for). A valid descriptive model is easier to develop but often the real value of the model comes from its predictive capabilities. Note that a descriptive model becomes a predictive model as soon as it is used as such. Also note that a valid descriptive model does not guarantee it is a good or even useful predictive model.

Some modeling activities and the relation to model types is presented below:

- **Performance assessment or design evaluation**: How good a job have we done. May require descriptive or predictive models.
- **Design**: How well will this system perform if built this way?. What characteristics of the design are the most important to the system performance (i.e., what are the important design parameters and how should they be altered). Requires predictive models.
- **Accident prevention, simulation or investigation**: What conditions led to the failure observed in the system? What conditions might lead system failure? Predictive models are usually required.
- **Control system synthesis**: Design a controller to make this system meet some performance specifications. The controller design methodologies presume the existence of an adequate model of the uncontrolled system. The model is usually developed as a descriptive model but is often used with a model of the controller to predict the “new” closed loop system performance (i.e., it is being used as a predictive model). This can lead to very inaccurate appraisals of the controllers performance.

Besides the engineering activity related reasons mentioned above, some of the advantages and disadvantages of using models are listed below:

Advantages:

1) Models are the only way to communicate with computers
2) Permits analyzing design performance that might otherwise be in possible.
3) Predict the behavior of a product before it is manufactured.
4) Simulate environmental effects which may be difficult or impossible to actualize on the hardware.
5) Evaluate alternative designs.

Disadvantages:

1) Models are approximations of reality. They are based on many assumptions that are often unknown to the model user.
2) Many physical phenomena are hard to model (e.g. friction).
3) Theory base insufficient (e.g. membrane transport, muscle models).
4) Data for determining parameters may be unavailable or to expensive to obtain.
5) Model approximations plus computer round off can yield errors without the modeler being aware.
6) Development costs can be very high. Some modern software packages help this situation.
7) Running the model can be expensive.
8) Model validation may be difficult and very costly.

Finally, if a model is supported by accumulated evidence it becomes a law. However, it may not be easy to solve (e.g. Navier-Stokes equations). Thus, in practice, models that can be effectively solved on a computer at the expense of some accuracy can be very useful. In addition, not all models can be validated (e.g., a model used for design) but still may be very useful (cost effective) in producing a prototype that is closer to the desired performance then one produced without the aid of models.