Assessing Information Content in Analytical Simulations

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Abstract:

Successfully managing design projects requires a vast array of skills, one of them being able to assess the actual information content in technical data and employing it in the design decision-making process. Honing this skill results in delivering conforming products within cost, on schedule, and which reliably meet performance targets. This tech brief looks at the role of information in the decision-making process and how analytical simulations, employing Analysis Leading Design (ALD), can increase the information content used at project decision points.

Information Generation:

Information is typically thought of as communication or reception of knowledge or intelligence which is intended to produce specific effects. Shannon's seminal work on information theory is based on the fundamental intuition that information and uncertainty are inversely related. The more information content a statement has the more uncertainty is reduced.

A statement "it is likely to rain in Seattle during the month of April", therefore, has virtually no information content. Even though the claim is very likely to correspond to reality it does not reduce uncertainty and it doesn't provide a basis for considering any actionable change. Most people traveling to Seattle in April would have packed rain gear. For information to exist, the communication reduces both uncertainty and provides a warrant for the consideration of actionable change. Analysis processes that create high information content will achieve both ends. The process will reduce uncertainty and provide greater insight into product performance making change, when required, efficient and productive.

Analysis Leading Design (ALD):

Analytical and/or simulation processes which have high information content flow top down. The process starts with simulations which can be independently validated by first principles. These models are high level and are used to efficiently study the influence of key design parameters on performance while also providing warrants for assessing later simulations which have greater granularity of elements in the system. What at first may appear to be only a unification process is also a form of deconstruction. It enables the individual contribution of elements to be assessed, as greater design definition is added in the modeling process. Understanding the contribution of an individual element is inherently a deconstructive process, but when done in the context of a system enables the value to be assessed simultaneously. As each analysis rests on information from simulations which have proceeded it, a wide base of product knowledge develops.

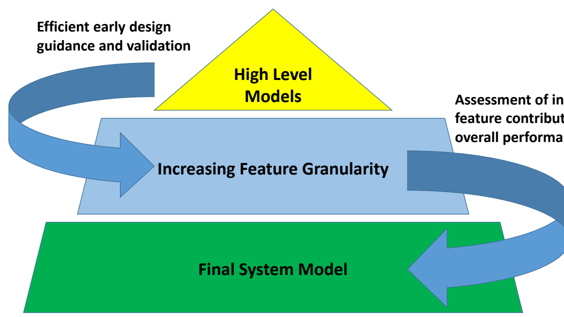

Figure 1 – Process with High Information Content

The ALD process is illustrated in ASME paper GT2012-68021 which discusses the design of a generator isolation system on a US Naval ship. High level models were used to guide the design within the cost, performance and spatial constraints imposed on the system. As the design congealed, models with higher element granularity were used to decrease uncertainty and identify modifications required to obtain system compliance.

As with all structural systems, the design variables can be categorized into three fundamental elements: Loads, Material, and Geometry. For high level models to provide design guidance and warrants for models with greater feature granularity, all three elements need to be accounted for. Effective high level models are simple and elegant but not simplistic.

Information Requires Context:

The outcome of ALD is a final system model which can be used to evaluate non-conforming parts in the system, make final adjustments during runoff, and provide a basis for evaluating the potential benefits of change in future products or systems.

In the case of the generator isolation system, the mass of one of the impedance rafts had been reduced by less than 10% to create a positive static margin on the shock/isolator mounts. This, however, decreased the transmission path impedance and the dynamic performance during runoff was initially non-compliant at the higher end of the frequency spectrum. During the design process the aft raft mass had been reduced because its contribution had only been considered as it related to the static capacity of the isolator mounts. The final system model was used, however, to quickly identify the root cause of the issue and additional mass was added back to the raft. This provided a nearly zero but positive static margin, and brought the dynamic performance back into compliance.

A similar study for a jet engine compressor case is currently underway. The process initially employed high level models with increasing feature granularity producing a final system empirically validated model. This model was used to set operating limits to facilitate engine certification. Due to the uniqueness of the external systems, anticipated challenges have been observed in service and now can be efficiently addressed using the virtual product actualized in the system model.

Fallacy of Affirming the Antecedent:

When initially employing a highly granulated feature model in the design process, a fallacy of affirming the antecedent often occurs. This is due to the lack of understanding of how individual elements are contributing to system performance. An example of this fallacy is illustrated in the syllogism; "without gas the car will not start, the car doesn't start, therefore the car is out of gas". Obviously, the conclusion may correspond to reality but not necessarily. There are many other potential contributors in the system that could be causing the observed performance. Such fallacies lead to wasted time and resources in problem solving and/or creating exposure to unforeseen risk in the future.

Employing a highly granulated feature model for the sole purpose of determining whether various performance benchmarks are met without understanding the relative contribution of components to the overall system performance can easily lead to affirming the antecedent. Even in highly engineered products, success can be experienced but not for the assigned reasons.

From a business standpoint, incorrectly affirming the antecedent may seem to be of little or no consequence if success is experienced. Strong and sustainable business models, however, operate on the premise that causation fallacies will eventually limit growth and profitability of an enterprise. The success of products based on fallacious warrants are either overdesigned or create business risks as mission demands change. The lack of information produces a reactive business posture which is unable to efficiently take advantage of changes in market demands or creates unwarranted risk exposure. Both can limit business growth and long term viability.

Conclusion:

Information is at the core of what makes productive decision making possible. It reduces uncertainty and provides a warrant for actionable change creating an environment for growth and profitability.

Employing high level models to guide the best path forward followed by greater modeling granularity in system elements as the design congeals is an efficient means for providing information to guide a project. This process, known as Analysis Leading Design (ALD), creates a stable project feedback system for course corrections, resulting in maximizing efficiency and minimizing total costs.

Analysis Leading Design also provides a means of avoiding relying on models with high granularity but little information content. In organizations involved in highly engineered products, periodic reviews of analytical work practices are vital in avoiding the pitfall of affirming the antecedent. Small group training sessions using case studies of ALD is an efficient means of nurturing a vibrant design culture which is information driven. Organizationally, these sessions can be successfully implemented either top down or bottom up. Incorporating ALD into the culture of a concern with highly engineered products can be an effective strategy for significantly increasing profitability.

Link to ASME paper GT2012-68021