Dumb and Dumber? The More You Learn, the More You Don't Know

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As I read the articles and editorials from the current and past issues of *Sound and Vibration* magazine, I realize that I really only know how to solve pretty simple structural dynamics problems. Yes, I can use and understand both theoretically- and experimentally-based methods, but most of the problems involving practical structural systems (cars, planes, machine tools, disk drives, etc.) are made up of a number of subsystems, hard-to-characterize connections and joints and, sometimes, nonhomogenous and nonisotropic materials.

These structural systems are quite complicated, and most of our tools work well when we restrict the problem to issues that are dominated by the linear characteristics of the involved system. The theoretical assumptions for our most commonly used tools (modal parameter estimation, modal and impedance modeling, model verification/validation and response simulation) are linearity, time invariance, and most times, reciprocity. For the past 10-20 years, many researchers and vendors have developed wizards (artificial intelligence methods, autonomous methods, automatic methods, etc.) that automatically apply these tools to measured data from realistic systems according to some internal and external rules. As long as we mostly work on fundamentally linear, time-invariant problems, these methods will, sooner or later, solve these problems successfully. We have to be careful to apply sufficient artificial intelligence (internal and external rules) to make sure we have reasonable physical results (in contrast to numerically sufficient results that can be easily generated by these inverse problems), but the methods already work well on simulated data. The reason that these methods have not already been more successful raises the question whether we have solved most of the major problems that can be characterized as linear, time invariant and reciprocal.

I do not believe that these wizard approaches will be successful at solving increasingly more difficult problems unless the proper data are provided to the wizard and the tools and rules available to the wizard are appropriate. In some areas of interest, work is well underway to solve these types of problems, but going to this next level is difficult, requires a higher level of math skills and a higher degree of appreciation for the pertinent theory, requires commitment of time, money and personnel and may or may not be needed by all industries.

So what have I been doing for the past 40 years? I have spent my career trying to educate myself and others with respect to noise and vibration concerns that arise from structural dynamics phenomena. A good portion of that effort involved trying to stay up with new technology. This means that I was often relearning how to solve old problems with new methods that involved new hardware and software solutions. Along the way, I believe I have developed an appreciation for the numerical and computer science issues of why some solution approaches work better than others, but I have mostly been successful when the problems are fundamentally linear.

Certainly, I can take many more channels of data in much less time, take advantage of redundant information in that data and process that data more efficiently in less computer memory or computation time, but I am not solving more difficult problems most of the time. When I am applying current technology to realistic systems, I focus fundamentally on linear, time-invariant structural dynamics thought processes. While we all have gotten much better at doing this, it is time to move on to the more difficult problems.

Engineers and scientists like to solve problems but also like to work problems that they know how to solve. Some refer to this as the hammer-nail thought process – if all you have is a hammer, everything looks like a nail. Engineers and scientists sometimes accommodate dynamic problems as static problems with a factor of safety. Certainly in our structural dynamics area, engineers and scientists cling to linear, time-invariant approaches when we know that most of the systems that are assembled have characteristics that are not linear and are not time invariant. In the past, these approaches have worked well but still have not solved some problems. While we sometimes forget, engineers and scientists live by the adage (credited to Albert Einstein and others): "Make everything as simple as possible, but not simpler."

As we move forward, we have to ask the question whether our current solution methods are too simple. Statistical methods may be increasingly required to account for build variation and small nonlinear or time-variant issues. Generalized models that can accommodate multiple loads (force, pressure, temperature, etc.) and account for nonlinear and time-variant considerations need to be considered for some structural systems, particularly systems that experience extreme environments of combined loads. Issues of multiple scales applied to time, frequency and spatial dimensions need to be considered for many problems. Tools that focus on detecting whether the current available tools are sufficient to solve a problem (the linearity or time-variant "check engine" light!) need to be developed.

Finally, the data acquired to validate or calibrate a model have to span the space of the required solution so that the nonlinear or time-variant issues are not obscured. Since we may not be able to test in some parameter regimes, how will we calibrate our simulation models? If we need to consider very high or very low temperatures, we do not have sensors that can measure the data anyway. These are all issues that are becoming increasingly pertinent. One of the discussion points of recent editorials and articles in *Sound and Vibration* involves how to educate our future engineers. Since engineers do many different things in many different industries, there is no unique answer to what needs to be part of an engineering education program. Much of what we do at the undergraduate level is dictated by requirements of the Accreditation Board for Engineering and Techology (ABET, www.abet.org), framed by the talents and interests of the involved faculty at a given institution. ABET incorporates input from industry, professional societies, government agencies and education institutions to try to ensure that nothing is missed. The needs of the engineering profession are very diverse, and the goal of any engineering institution should be to educate engineers so that they will be able to respond to a career of changing, diverse requirements that may entail individuals re-educating themselves several times during a career.

Even as structural dynamics problems become more and more complicated, the fundamentals of linear, time invariant methods will still be the bedrock of what we teach, but appreciating the problems outside this limited framework, both theoretical and experimental, needs to be communicated to our future engineers as well. Having said that, most Bachelor of Science or Engineering degrees are still only 4 to 5 years long for an undergraduate education. Think back on your own engineering or science education; how much can we drop out because it is no longer pertinent, and what should we add that is critical? This is not an easy decision, but it does highlight the need for the advanced degree for many practicing engineers and scientists if more demanding issues beyond the linear and time-invariant limitations are important to a particular job situation.

I hope this gives you something to think about, and I am always interested in hearing your thoughts on my musings. If you have any comments, please feel free to contact me – randall.allemang@uc.edu. SV