Ten Levers of Smart Engineering

Dr. Aloknath De, SrVP and CTO, Samsung India-Bangalore

Smart Engineering is all about using insights to conceive, model and scale an appropriate solution to a problem or an objective. Scientific, economic, social, and practical knowledge is applied in the process. This knowledge serves as an engine behind designing, building and maintaining structures, machines, systems, materials and even processes. Smart Engineering brings 'wow' element in user mind and significant societal benefits.

This article explores numerous motivations and techniques that go around smart engineering. In the following, the broad classifications are captured as ten levers of smart engineering:

- **Need-of-the-Hour Engineering:**

  History records that different era have laid stress on different aspects of engineering. In B.C. period, people have focused on primitive technology for agriculture---studying soil characterization, improving irrigation system, and finding means of land-ploughing for harvesting. As civilization moved from stone age to metal age, society learnt to cook and prepare food. Agriculture to heavy engineering to electronics engineering ---various themes have got emphasis during India's series of five-year plans. In present day, physical highway (roadways, airways) and information superhighway (internet2 upcoming) are making our living world a global village. Mobile phone reaching to masses has enhanced our productivity. From world of voice and SMS, instant messaging and usage of context and social media are becoming prevalent. Today's **Need-of-the Hour Engineering** is around wide deployment of broadband and connectivity, and optimization of required infrastructure.

- **Improvised Engineering:**

  I call second lever of smart engineering as **Improvised Engineering**. This deals with how same or similar purpose is achieved by more sophisticated technology. For example, in early days, shadow from an anchored stick used to give relative time-of-the-day. Sun Dial and Jantar Mantar are subsequent developments. Currently, we have watches of all type including high-precision instrument that captures split-second difference between winner and runners-up in Olympics 100-meter race. Let me take another example of printing. At some point, offset printing was almost the only way. Digital printers have seen journey from dot matrix to laser jet. 3D printing is bringing forth a paradigm shift from subtractive printing technique to an additive one. Similarly, Graham Bell's invention of telephone equipment to today's wireless connection is a steadfast progress. Smartphone has enriched voice communication but also has eased file sharing and multimedia data transfer.

- **Strip-Down Engineering:**

  Curiosity of knowing "what goes inside a product design?" gets satiated to a great extent by *reverse engineering*. How many people have tried to unravel Coke's signature formula? We also hear about *frugal engineering* which drives down the cost factor but at times misses to maintain durability aspect of product. I term the third lever of smart engineering as **Strip-Down Engineering** that combines the strengths of reverse engineering and frugal engineering. The engineering smartness here is built around applying Pareto's 80:20 principle and analyzing how to keep essential functionalities. The goal is to select top 80% features from user perspective and implement them with 80% cost reduction. For example, in a low-priced car like Nano, question arises as to whether three nuts can tighten the tyre instead of four. Need for every element is critically questioned. Strip-down engineering constantly weighs cost-benefit structure and is a great vehicle to build product for bottom-of-pyramid segment population.

- **Performance-Boosting Engineering:**

  Success of a product or service lies in its performance by relative as well as absolute measures. **Performance-Boosting Engineering** targets to enhance solution performance keeping constraints in mind. Let us take the example of mobile phone where we currently leverage even octa-core processor. The evolution from single-core to octa-core has been a way to incorporate parallelization and increase processing power. In heterogeneous processing environment, appropriate partitioning of code across ASIC, DSP, CPU, GPU, MCU chips significantly drive up system performance. This category of smart engineering also encompasses developing multi-resolution systems, such as a spectrum of products from phone-with-full-connectivity-but-basic-camera to higher-resolution-camera-but-basic-phone-connectivity. This class of smart engineering facilitates introduction of more complex features, reduces response time or boosts other system performance metric.

- **IntelliSys Engineering:**

  Intelligent devices employ functions of sensing, actuation and control through sensors, actuators and controllers. When the goal is describing and analyzing a situation, and taking decisions based on the gathered data in a predictive or adaptive manner, smart actions become essential to be performed. **IntelliSys Engineering** empowers intelligent systems---promotes autonomous operation based on closed-loop control, energy efficiency and networking capabilities for a platform or a system to be intelligent. Let us assume that we want to measure how much energy is consumed in a typical home? Energy consumed when the tariff depends on the time-of-day? Similar to smart home platform, we can consider a connected car platform where tyre pressure sensors in each tyre sense a-priori flat tyre situation. IntelliSys engineering for connected car enables to build cars that aid in navigation, cars that go driverless, cars that talk to each other by wi-fi technology, cars that will even fly!

- **Cross-Pollination Engineering:**

  By now, we have covered five categories of smart engineering and I have given illustrations from various faculties. Studying one field dries up ones idea! Newer fields are emerging. And solutions for some problems require extensive knowledge of multiple faculties ---either to tie ideas up, or to learn from one field and apply to another. This is what I term as **Cross-Pollination Engineering**. For example, knowledge of geology, soil engineering combined with biology helps to address problems pertaining to geo-microbiology. This helps us understand how bacteria and virus come to our food

through soil contamination and what possible remedies could be taken up. Geography knowledge in conjunction with information system expertise paves way for geo-information system (GIS). Similarly, material science covers wide range of special materials meant for nano-electronics to vehicle bodies. Cross-pollination engineering gives birth to new fields like fiber optic communication that combines optical physics with telecommunication. The field of music, coupled with acoustics engineering, opens a chapter of musicology by cross-pollination of subtleties in both fields.

- **Smart-Auxiliary Engineering:**

  Majority of times, engineering takes scientific discoveries forward in the form of products and utilitarian services. At times, engineering plays second fiddle to scientific projects---It helps in next-level of scientific discoveries through infrastructural support. Let us consider Large Hadron Collider mega project recently conducted in CERN, Geneva. The very simulation of *Big Bang* has been an engineering feat---this has been a pre-requisite to determine what happens after the big bang event. Support role of engineering should not be misconstrued as engineering trivia. One mouse can bother an elephant! One bird can hit a plane and knock it down. We recently found that Dreamliners have used, instead of Nickel Hydride, Li-ion batteries that produce twice the energy in half the space. However, pressure, and heat wear out the insulation and may cause short-circuit resulting in fire on flight path. We truly understand the importance of **Smart-Auxiliary Engineering** when we analyze how all Dreamliner flights were grounded worldwide because of batteries!

- **Sustainable Engineering:**

  Benefits that science bring are transpired through technology products in daily life. In order to promote *green* concept, we are reducing use of thermal energy and going for solar and nuclear energy. Not just the power generation, smart grids are being conceived for better power distribution. **Sustainable Engineering** encourages that we build products that consume less energy and make a zero-sum game with environment. Let us take example of electronic circuitry. Researchers have progressed to operate digital chipsets in 1.8 V instead of 3V or 5V. Energy-aware protocols have also been designed. These techniques substantially help in overall power reduction for electronics equipments. Sustainable engineering addresses concerns around energy consumption, electro-magnetic radiation hazard produced by cell towers and so on. How to reduce contamination and even re-purify natural resources for our well being is the concept behind sustainable engineering that impacts product design phase.

- **Nature-Inspired Engineering:**

  It looks gorgeous when city parks decorate vegetation in the form of horse or elephant! We can also design usable products inspired by flora and fauna. Cranes are built mimicking long-necked giraffe. Mercedes-Benz bionic concept vehicle has been designed understanding low coefficient of drag and rigid exo-skeleton of Boxfish. In Japan, the first design of bullet train running at 200 mph had been an engineering marvel, but had one problem: as it comes of a tunnel, it produced a loud noise. This problem was resolved by studying beak of kingfisher as it swoops down to catch fish, touch the water surface and then go back up. Look at our national flower lotus. The lotus leaves manage to remain free of contaminants as they possess a field of small bumps and dust is easily picked up by water drops. The same principle is used in exterior paints, textiles and so on. **Nature-Inspired Engineering** study objects and phenomena from nature to understand how a fundamental scientific principle works in daily life and apply the notions in product design.

- **Forward-Looking Engineering:**

  Engineering foundations that are based on strong theory and driven by science can be quite forward-looking. Information theory to game theory, number theory to string theory all have been playing role in telecommunication, cryptography and other associated areas. Let us think about how physical world and digital world are fusing! Technology is moving from virtual reality to augmented reality. User interactions are changing from touch-base to gesture-controlled. Integration of audio, visual and haptic feedback is becoming part of next user interaction. Let us consider quantum cryptography as another example of **Forward-Looking Engineering**. Quantum computing uses qubits with superposition and entanglement. Using these basic principles, quantum teleportation allows same entity to be in two places simultaneously, but observation decoheres. Forward-looking engineering aims to manifest scientific ideas or even science fiction concepts to reality.

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