digitaleng.news //////

DE

Digital Engineering

June 2017

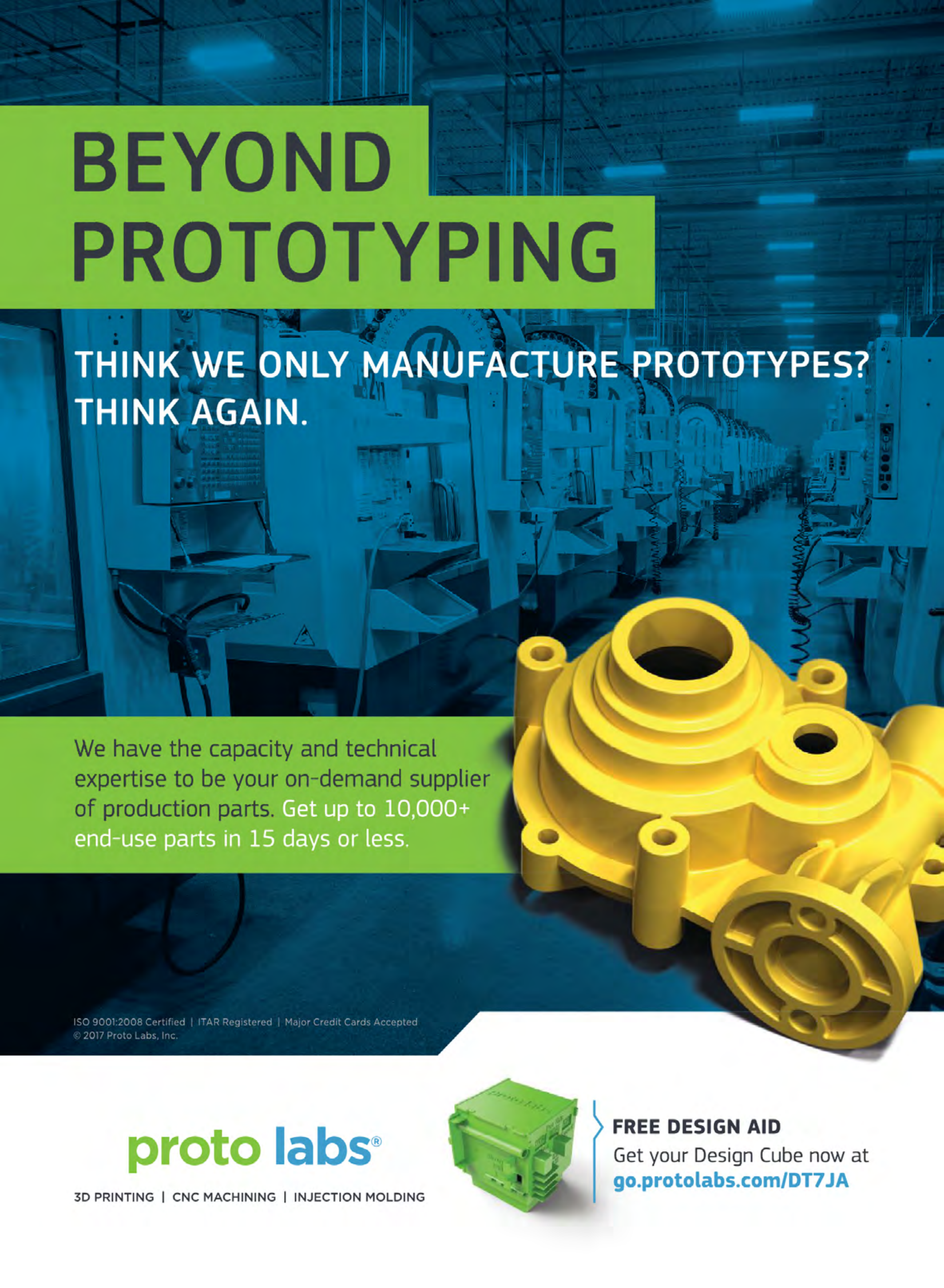
FOCUS ON: IoT P.42

Flying on Water

REVIEW: AUTOCAD 2018 P.33

TOPOLOGY OPTIMIZATION P.36

HIGH-PERFORMANCE DATA ANALYTICS P.42


BEYOND PROTOTYPING
THINK WE ONLY MANUFACTURE PROTOTYPES? THINK AGAIN.
We have the capacity and technical expertise to be your on-demand supplier of production parts. Get up to 10,000+ end-use parts in 15 days or less.
ISO 9001:2008 Certified | ITAR Registered | Major Credit Cards Accepted
© 2017 Proto Labs, Inc.
proto labs®
3D PRINTING | CNC MACHINING | INJECTION MOLDING
FREE DESIGN AID
Get your Design Cube now at
go.protolabs.com/DT7JA

by Jamie J. Gooch

Technology vs. Economy and Human Nature

ANNOYED VOICES fill the gate area at the airport terminal as I write this. They're annoyed because our early-morning, 45-minute flight from Cleveland to Chicago is delayed by at least two hours due to a maintenance issue. The mechanics who can hopefully address the issue and get us to the Windy City are flying in from Columbus.

The gate agents are getting annoyed, too. I can hear it disguised in their tone as they redirect questions like "Why don't you have mechanics here?" and "Don't you have another plane?" with polite offers to help the would-be passengers make their connections. The customers asking such questions already know the answers, just like they know the gate agents aren't responsible for the mechanical problem on the plane. It doesn't pay for an airline to keep extra mechanics and airplanes on standby, just in case a problem arises. The travelers are tired and upset, and feel the need to vent their frustrations.

I'm tired and a bit upset myself. I woke up at 3:30 a.m. to catch the early flight so I could attend a conference today. I use my suddenly free time to edit the articles in this issue, reading about the promise of connected technologies to provide, among other benefits, predictive maintenance. Knowing that airlines already have robust predictive maintenance plans in place and that the aircraft's maintenance problem might have been avoided with the right stack of new technology does little to ease my frustration. "Why didn't the airline use sensors, Big Data analytics and high-performance computing in an integrated platform to fix the part before it failed?" I want to ask the grumpy business exec sitting beside me at the gate. I don't. I already know the answer. I'm just venting my frustrations.

Technology, Time and Money

The experts who are supposed to know these things say the market for the Internet of Things (IoT) is expected to double its install base between 2015 and 2020, reaching 75.4 billion in 2025 (see page 8). I have no reason to doubt them. One of the best things about editing *Digital Engineering* is the opportunity to see, first-hand, mind-blowing examples of companies using cutting-edge technologies to design better products and systems, improve efficiencies and cut costs. One of the worst things about editing *DE* is experiencing how many companies are not using cutting-edge technologies to design better products and systems, improve efficiencies and cut costs.

I know it's still early for the industrial IoT. I know it's complicated and expensive to rework and integrate sprawling legacy systems and processes. However, I also know the amazing feat of engineering that is human flight is too often a frustrating experience at best.

Cultural Challenges

The captain of the plane has arrived at the gate. He does not look annoyed. He looks chipper. You might think this would annoy me further, but I'm glad he isn't upset by something as trivial as a two-hour delay. We don't need a cranky pilot or an unsafe plane. As he heads through the security door, the gate agent announces that he is going to speak with the maintenance staff about the repairs. Also, we should feel free to help ourselves to some free snacks while we wait.

The announcement has the intended effect. A confident, experienced looking person in a snappy blue uniform, complete with a cap, is on top of the situation. Plus, there are free snacks. Grumbles are muffled by Cheez-Its and drowned out by bottles of water. Sometime later the agent announces that boarding is beginning. The plane will arrive in Chicago 15 minutes earlier than the originally estimated delay. The airline under promised and over delivered, in a way.

Time will tell whether the industrial IoT has done the same. I wonder which captain of technology is taking charge and proving that their products provide an acceptable return on investment—that the industrial IoT does pay. I wonder how long it will take. I wonder which ones are taking the complaints of their clients' customers into account during product development.

Then the boarding process begins. I take a drink of my free water and keep typing. I'm in the back of the plane, so I'm in no hurry. I'd just have to wait anyway as people seated in front of me who boarded first block the aisles while trying to squeeze their carry-ons into the overhead bins.

It's not enough for technology to work, or for it to make sense economically. It also has to shift cultural norms that tend to embrace the status quo. **DE**

Jamie Gooch *is editorial director of* Digital Engineering. *Contact him via jgooch@digitaleng.news.*


ALTAIR PRESENTS
SURFACE TO AIR
ENGINEERING FLIGHT
Artemis
GUNVOR
Artemis
ULYSSE NARDIN
Dive inside the competitive sailing world with Artemis Racing and their campaign for the 2017 America's Cup. See how Altair is helping Artemis Design the Difference™ as they pursue the world's oldest and most coveted yachting prize.
Watch the film at designthedifference.com

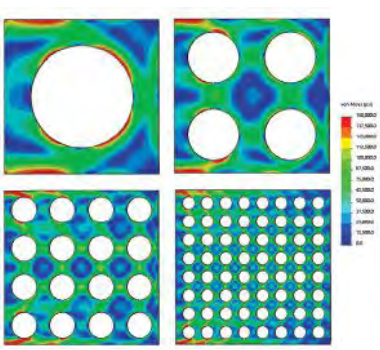
DE
Digital Engineering
TECHNOLOGY FOR OPTIMAL ENGINEERING DESIGN

INSIDE

digitaleng.news
June 2017
Vol.22 • No.10

SPECIAL COVERAGE

FEATURES



ON THE COVER:
© Sam Greenfield/
ORACLE TEAM USA

FOCUS ON THE INTERNET OF THINGS

DEPARTMENTS

PUBLISHER
Tom Cooney

EDITORIAL
Jamie J. Gooch | Editorial Director
Kenneth Wong | Senior Editor
Anthony J. Lockwood | Editor at Large
Stephanie Skernivitz | Associate Editor
Sarah Petrie | Copy Editor

CONTRIBUTING EDITORS
Tony Abbey, Brian Albright, Mark Clarkson, David S. Cohn, Tom Kevan, Randall Newton, Jim Romeo, Beth Stackpole

ADVERTISING SALES
Tim Kasperovich | East Coast Sales
440-434-2629
Jim Philbin | Midwest/West Coast Sales
773-332-6870

ART & PRODUCTION
Darlene Sweeney | Director
darlene@digitaleng.news

A PEERLESS MEDIA, LLC PUBLICATION
Brian Ceraolo | President and Group Publisher

ADVERTISING, BUSINESS, & EDITORIAL OFFICES
***Digital Engineering®* magazine**

Peerless MEDIA, LLC

Peerless Media, LLC
111 Speen St., Suite 200,
Framingham, MA 01701
Phone: 508-663-1500
E-mail: de-editors@digitaleng.news
www.digitaleng.news

Kenneth Moyes | President and CEO, EH Media

SUBSCRIBER CUSTOMER SERVICE
***Digital Engineering®* magazine**
PO Box 677 • Northbrook, IL 60065-0677
Phone: 847-559-7581
Fax: 847-564-9453
E-mail: den@omeda.com

BPA WORLDWIDE

Digital Engineering® (ISSN 1085-0422) is published monthly by Peerless Media, LLC, a division of EH Media 111 Speen St., Suite 200 Framingham, MA 01701. Periodicals postage paid at Framingham, MA and additional mailing offices. *Digital Engineering®* is distributed free to qualified U.S. subscribers. **SUBSCRIPTION RATES:** for non-qualified; U.S. $108 one year; Canada and Mexico $126 one year; all other countries $195 one year. Send all subscription inquiries to MeritDirect, *Digital Engineering®*, PO Box 677, Northbrook, IL 60065-0677. ***Postmaster:*** Send all address changes to MeritDirect, *Digital Engineering*, PO Box 677, Northbrook, IL 60065-0677.


ENGINEERING SIMULATION
VIRTUAL PROTOTYPING
TRUE AUTOMATIC
+EDGES

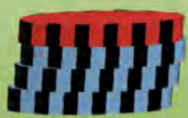
Place Your Bets on 2020 IoT Growth

$7.065B

Global IoT revenue will reach $7.065 billion by 2020, up from from $2.712 billion in 2015.

— *"IDC Market in a Minute: Internet of Things"*

30.7B



The installed base of IoT devices will reach 30.7 billion in 2020 and 75.4 billion in 2025, up from 15.4 billion in 2015.

— *"IoT platforms: Enabling the Internet of Things," IHS, March 2016*

$151B

The Industrial Internet of Things (IIoT) market will reach $151 billion by 2020.

— *"Industrial IoT Market by Technology, Software, & Geography, Markets," Mind Commerce, LLC*

$470B

Annual revenues for IoT vendors could exceed $470 billion by 2020.

— *"How Providers Can Succeed in the Internet of Things," Bain & Company*

The Executive View of the Industrial IoT

41%

41% of executives expect the industrial IoT to have a significant or major impact on their industry within three years.

Just **1.5%** of executives at large companies say they have a clear vision for the industrial IoT with implementation well under way.

55%

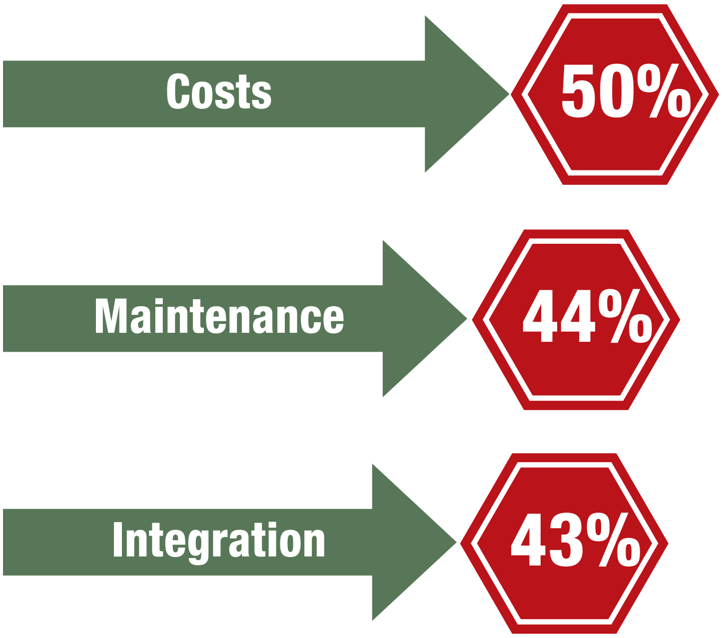
55% of executives say industrial IoT is gaining adoption within their industries, including both pilots and larger-scale adoptions.

IIoT Investment Focus

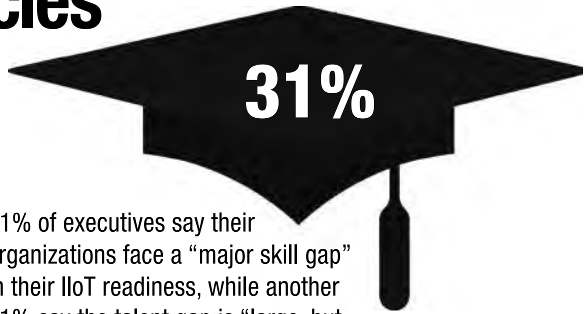
- New Products & Services 35%
- Customer Touchpoints 29%
- Manufacturing 23%

— "The Impact of Connectedness on Competitiveness," Business Performance Innovation (BPI) Network, April 2017

IoT Implementation Obstacles

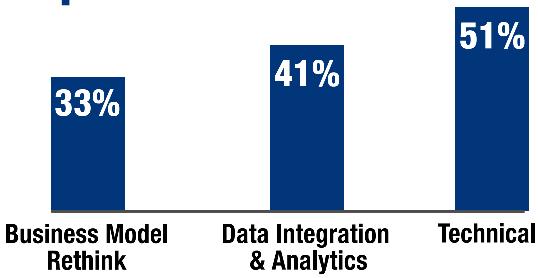


— *"The Internet of Things: Today and Tomorrow" Aruba, a Hewlett Packard Enterprise company, February 2017*



31% of executives say their organizations face a "major skill gap" in their IIoT readiness, while another 31% say the talent gap is "large, but improving somewhat."

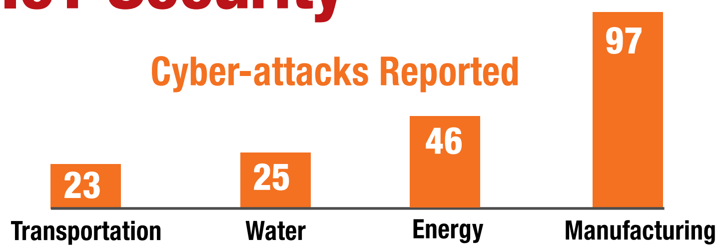
Top New IoT Skills Needed



— "The Impact of Connectedness on Competitiveness," Business Performance Innovation (BPI) Network, April 2017

IoT Security

Cyber-attacks Reported



The manufacturing sector is, by far, the leading target of infrastructure cyber-attacks, accounting for one-third of the 295 total attacks reported in 2015.

— *"NCC/ICS-CERT Year in Review," The U.S. Department of Homeland Security, 2015*

84% of organizations have experienced an IoT-related security breach.

— *"The Internet of Things: Today and Tomorrow" Aruba, a Hewlett Packard Enterprise company, February 2017*

- 62% have no idea where their most sensitive unstructured data resides.
- 66% don't classify this data properly.
- 63% don't audit use of this data and alert on abuses.

— *"The Data Security Money Pit: Expense In Depth Hinders Maturity," conducted by Forrester Consulting on behalf of Varonis Systems, Inc., January 2017* by Tom Kevan

Designing for Harsh Environments

AS SENSORS RISE TO PROMINENCE with the growing footprint of the Internet of Things (IoT), a close look at the sensor nodes populating the digital landscape reveals boards and chips packed with supporting computing, data storage and communications units. Couple this digital overpopulation with growing deployments of nodes in harsh environments, and you begin to appreciate the scale of the challenges facing design engineers.

Key among these challenges: temperature extremes and electromagnetic interference, which can corrupt data and even trigger system failure. The good news is that designers can counter these factors. Following are some best practices.

Taking the Heat

Harsh environments run the gamut of temperature extremes, from sweltering heat to sub-zero temperatures. Both conditions pose serious threats to a design's efficacy. Low temperatures can diminish the efficiency of electronic components, reducing system reliability by changing values or creating timing errors. High temperatures, on the other hand, can trigger various issues.

One such condition, called "thermal runaway," comes into play when temperature spikes cause the semiconductor to release energy. This increases system temperature and can ultimately lead to system failure. Engineers can prevent thermal runaway by incorporating current-limiting protection. Here, the designer has several options, which include using thermal fuses, circuit breakers or positive temperature coefficient current limiters.

Problems associated with thermal cycles also include issues arising from differences in thermal-expansion coefficients. A variety of materials make up electronic circuitry, the substrate on which it's built and the encapsulation materials connecting the various components. Each material has its own thermal-expansion coefficient. Temperature changes cause the materials to expand and contract at different rates, compromising system interconnections. Compounding the situation, problematic interactions also occur between different materials at high temperatures.

Engineers can avoid these problems by choosing components certified for high-temperature operations and by matching thermal-expansion coefficients of materials in their designs.

Minimizing the Effects of EMI

Another factor to consider when designing devices and systems for harsh environments is electromagnetic interference (EMI). This phenomenon is produced by an external source—such as power switching circuits and RF devices—that affects electrical circuits via electromagnetic induction, conduction or electrostatic coupling. EMI can be conducted physically or radiated via the air.

Designers can mitigate the effects of EMI by adopting a few well-established practices. These include grounding all electronic equipment and shielding electronics and cables with conductive or magnetic materials to prevent incoming or outgoing electromagnetic frequency (EMF) emissions. An example of this can be seen in smartphones, where a metallic shield protects electronics from emissions from its cellular transmitter/receiver.

EMI abounds in application areas like industrial environments, far outpacing its presence in consumer and in-home electronics. One reason for this is that industrial applications tend to use more electrical devices with higher voltages and currents.

Another tool in the designer's arsenal are EMI filters. These passive devices suppress conducted interference found on a signal or power lines. Most systems and devices contain EMI filters, either as separate units or embedded systems. These components include line filters, capacitors and inductors.

Aside from these specific solutions, engineers should follow a few general rules of thumb:

- make establishing EMI protection an upfront process, where you consider what measures to use when designing the circuit;
- position any section that can be exposed to EMI as far as possible from sensitive circuitry; and
- block interference as close to the source as possible.

Further Complications

Although effective techniques have been developed to address temperature extremes, EMI and other harsh environment challenges, the components required to implement these strategies are sometimes unavailable. The sad fact is that the market has a limited pool of products. As the IoT takes shape and harsh-environment applications become more prevalent, increased demand may cause vendors to remedy this situation. DE

Tom Kevan *is a freelance writer/editor specializing in engineering and communications technology. Contact him via de-editors@digitaleng.news.*

BOXX Pro Virtual Desktop Infrastructure (ProVDI™) breaks new ground for content creators using graphics-intense 3D applications. The only VDI solution for CAD and design professionals, **ProVDI™ 8401R-V** enables an organization to host multiple users on a single physical server without sacrificing performance and offers a unique, scale-out approach to single-threaded productivity within a virtual environment.

Intel® Core™ i7 processor
Intel Inside®. Extraordinary Performance Outside.

® Intel, the Intel Logo, Intel Inside, Intel Core, and Core Inside are trademarks of Intel Corporation in the U.S. and/or other countries.

888-984-7589
512-835-0400
www.boxx.com

BOXX

| CONSULTANT'S CORNER |

DESIGN

by Amy Rowell

Designing "Smart" Products

THE IOT (INTERNET OF THINGS) has invaded the consumer market—with wearables like the Fitbit; smartphones that track our music preferences and fitness levels; and home monitoring systems that allow us to detect intruders, and control lighting and heating remotely. Clearly, the makers of such IoT-enabled products are eager to collect performance data, preference data and usage data from their connected devices in an attempt to better serve (and anticipate the needs of) their existing customers and to explore potentially new markets altogether.

But are we at risk of becoming just a bit too enamored with the potential returns to be gained from such connected, "smart" products and the IoT? To the point that we risk overlooking the obvious: the relevance of the product design itself?

Enter "Juicero," an IoT-enabled high-tech juicer that seemed to be well-positioned to address a new market—the demand for healthy, easily produced, freshly made juice at home via a personal, at-home juicer. It features all of the potentially valuable attributes of a smart, connected consumer appliance—the ability to monitor the types of juices purchased, the frequency with which they are consumed and, as product supply dwindles, the ability to prompt the customer to reorder supplies.

The Juicero was backed by the likes of venture capitalist investment firm Kleiner Perkins Caufield & Byers and has been touted as the "Keurig for juice." But there is one fundamental issue with this product concept that its creators seemingly failed to recognize, as did its Silicon Valley investors. It turns out that the juice packet designed to be used in conjunction with the juice maker can be squeezed just as easily by hand as it can be by the high-priced ($400) Juicero juicer machine.

The Market, not Technology, Drives Design

How did this oversight happen? What can we learn from this product design/marketing flaw? What are the implications for IoT product design initiatives moving forward? Here, the lessons seem obvious, but are worth reiterating. Product design cannot be driven by technology—it must be *enabled* by technology. And market demand must serve as the driver for the product development effort—not the other way around. In the case of Juicero, which provides a service that can readily be achieved *without* the aid of technology, the implications are clear. Why invest in an expensive IoT appliance when a consumer can accomplish the same task at little cost—without it?

Of course, hindsight is always 20/20. But what Juicero developers and their investor friends could have done to avoid this simple oversight would have been to ask a basic question: Is this product uniquely qualified to perform a particular task or to deliver a particular service? If not, why would a customer want it? Can the product (or service) provide something—*not to its developers, but to the consumer*—that would be difficult to obtain elsewhere, or simply cannot be easily obtained elsewhere? A simple SWOT (strengths, weaknesses, opportunities and threats) analysis should have shed light on this with the Juicero. The question is: What prompted both the investors and the creators to overlook such basic analysis early on?

The answer provides another valuable lesson to be learned. In the development phase of any product, IoT-enabled or otherwise, one must not overlook basic design principles. A new product must be able to compete in the marketplace, not simply by virtue of its technology but by the function it serves, and most importantly by the market need it is able to address. Losing sight of this fundamental concept can spell failure for any product. Here, perhaps the mantra should be that "smart design" trumps the notion of any "smart product." Unfortunately, in the midst of the IoT craze, much like the VC investment environment that characterized the dotcom era, investors and product developers are often blinded by the promise of a new technology.

The bottom line? Simply because a product is IoT-enabled doesn't mean it's destined to be a winner. In fact, without a well-planned IoT strategy, even a well-designed IoT-enabled device that successfully meets the market need test will be subject to failure in the marketplace if it fails to deliver on its promise of "connectedness," reliably. But that's a topic for another discussion—the software development challenges associated with IoT-enabled products. DE

Amy Rowell *(linkedin.com/in/aarowell) is an industry analyst with a passion for researching topics related to innovation in next-gen product design and manufacturing and all the tools that are making it possible. Contact her via de-editors@digitaleng.news.*

| CONSULTANT'S CORNER |

IOT DATA

by Chad Jackson

Connectivity, Smart Software & Machine Learning

TODAY, THE LANDSCAPE OF THE INTERNET OF THINGS (IoT) is awash with new and exciting technology that can empower miraculous product capabilities. Collecting and analyzing the right data can yield insights that may hold the power to transform a company. Building the right intelligence and automation can transform an industry. The visions are grandiose. Yet, most companies today struggle with a short and simple question: *How do we get there?*

Most people know the basic technical steps. You have to collect the data. You have to analyze the data. You have to act on the data. All of that is easy enough to understand—at a high level. Drilling down into the details, however, is not so easy. In fact, most companies don't follow a straight line from here to there. There is a lot of meandering, quite a few mistakes and much learning.

Collecting the data is often one of the simplest yet most technical aspects of an IoT initiative. You can instrument a product with tons of sensors. You can stream those readings somewhere on the cloud. Likewise, taking action also can be simple. Once you have some correlation between sensor readings and some event, catastrophic or marvelous, most know what needs to come next: avoid it or repeat it. But the data analysis bit? Well, that can be terribly difficult. This part is where we are trying to find the needle in the haystack. How do you manage that?

In my time working with manufacturers, I've seen successful companies take one of two approaches to analyzing data. Both approaches share a common trait: controlled scope and focus. As you may or may not know, getting overwhelmed with Big Data can be a project killer. So, let's look at each in turn to see how these strategies keep things under control.

Boiling the Ocean… in R&D

The first successful approach I've seen employed is ambitious in some ways, yet focused in others. Here, companies instrument a product or prototype extensively. However, they don't do this in a production environment—at least not initially. They put this instrumented product through the paces as they would a prototype in testing. They expose it to a variety of cases and collect everything.

Once they have some critical mass of data, they don't try to analyze the data themselves. Frankly, there's just way too much of it. They turn machine learning software loose on it. They might feed it their initial hypotheses about what they think are the potential correlations. But by and large, they are looking for the software to bring them the key findings.

Companies in this mode are looking to learn. They are in the midst of discovery, and they know it. They kick off this kind of effort, but keep it under wraps in an R&D department. They aren't looking to disrupt current development projects. Findings from this kind of project will be applied in future projects that likely have not even been started yet. However, many findings from this kind of effort could have wide-ranging impacts across the company. There is great potential here.

Proving or Disproving a Hypothesis

A different approach comes in the form of an organization that is looking to achieve something very specific. They have a particular event with some kind of key business impact associated with it that they want to be able to predict. Furthermore, in this case there is a technical team who has a few ideas on what sensor measurements could be correlated to that event. In general, these organizations aren't looking to learn in a broad sense. They are looking to prove or disprove a hypothesis.

In this case, there is very limited and specific instrumentation. They are only looking to capture the data that will let them verify their idea or not. Because of that, there is a limited amount of data and the data analysis is simpler.

Findings from these kinds of efforts can be applied relatively quickly, depending on the complexity of the development project. And, they can provide value to the company quickly. Yet, their value is highly dependent on that single hypothesis.

Takeaways

There is no reason that a company couldn't pursue both of these kinds of projects. The first might even feed into the second. In fact, a company might run multiple projects of each type. But in both cases, the scope is defined and controlled.

IoT efforts can be terribly complex, but breaking them down into piecemeal projects makes these efforts far simpler. DE

Chad Jackson *is president of Lifecycle Insights (lifecycleinsights.com). Send email about this commentary to de-editors@digitaleng.news.*

ROAD TRIP
Engineering Conference News

3D Printing Alliances Build Bridges to the Future

BY STEPHANIE SKERNIVITZ

THIS YEAR'S RAPID + TCT conference for additive manufacturing brought thousands of attendees to Pittsburgh, aka the Steel City and City of Bridges. It was an appropriate venue, given the focus on materials, including metal, and partnerships.

The idea of building bridges threaded various components of the show together, be it companies announcing collaborations or speakers advising that the industry's strength lies in working together. The floor hosted hundreds of manufacturers of materials, printers, scanners, accessories, post-processing equipment and more.

Almost 350 booths filled the exhibit hall at Rapid + TCT 2017.

Kicking Things Off

"You haven't seen anything yet," Mickey McManus, research fellow of Autodesk and chairman at MAYA, boldly told the audience during the opening keynote as he shared his vision of the industry's future and how to move forward.

He talked of the infinite loop among making and learning and trends. "The future of making things and learning things is radically changing," he says, as he delved into the philosophy behind making things, and asked: "If we can make anything and we can make it right, what is the right thing to make?"

He added that it's not about just one big megatrend of everything being connected in the world of Internet of Things, for example. The IoT is intersecting with some other megatrends as well, including digital manufacturing, machine learning and generative design.

In hypothesizing about what's to come in the realm of generative design, McManus said, "The generative design idea goes such that we basically set a few set points and a few goals and then the system plays with us, sort of like a jazz improvisation. This is an exploration of what would happen if one person had the power of 10,000 engineers."

The power of 10,000 engineers could fuel another group with a visible presence at this year's RAPID. Rob Gorham, the executive director of the not-for-profit America Makes in Youngstown, kept the show rolling with an announcement of the new America Makes @ program.

The goal for America Makes is to establish more relationships with more organizations to advance the additive manufacturing industry. The program will offer cost sharing credits in lieu of annual membership dues to allow members and nonmembers to receive dollar credit for specific activities the group recognizes such as attending America Makes only events, or offering discounted services, for example.

MORE → digitaleng.news/de/?p=36878

From the Show Floor: Rapid Product Highlights

BY PAMELA WATERMAN

Metals and monitoring. Serial production and scalability. Process control and price optimization. At this year's RAPID + TCT conference, the vocabulary was mostly that of the manufacturing, not prototyping, world. The buzz in the exhibit hall proved a high level of interest in all-things additive, worldwide, and confirmed the movement of additive manufacturing (AM) technologies into mainstream industrial applications.

With the AM industry now more than 30 years old, it seems people are finally "getting it." The bigger picture tasks identified in a keynote panel by 3D Systems president Vyomesh Joshi were productivity, repeatability, durability and how to make them cost-effective in the realm of AM.

Long-time players in this field, well-established companies recently branching into AM, and dynamic newcomers all brought fresh products and ideas to share and show. Splitting time between tech talks and exhibitor booths was kind of like speed dating with so much to see and learn in such a short time.

Check out highlights of what *DE* found to be impressive from the almost 350 booths.

MORE → rapidreadytech.com/?p=11529

3D Printing Eliminates Healthcare Barriers

BY KENNETH WONG

SURGEONS, DOCTORS, dentists, researchers and medical students filed into the University of California-San Francisco Mission Bay Campus for the 3DHEALS 2017 Conference April 20. Over the next six hours or so, through nine different panel discussions, the speakers and attendees explored the effects of 3D printing applications in healthcare, ranging from regulatory concerns and IP issues to biomaterials.

3DHEALS, according to the organizers, aims to "[foster] a global collaborative and innovative healthcare 3D printing ecosystem."

The challenges, advantages, and benefits brought up by the attendees—the need for manual cleanup of digital data and the use of 3D printed models as a communication tool, to name but two—may sound oddly familiar to those in automotive, aerospace and consumer goods.

Speaking to Patients in 3D

In the panel focusing on different 3D printing applications for healthcare, Peter Liacouras, director of services for 3D Medical Applications Center, Walter Reed National Military Medical Center, said, "I feel, our strength is in inter-professional communication. We have to be able to speak the doctor's language, but also the engineer's language."

Paul D'Urso, neurosurgeon & founder of Anatomics, recalled a charity case he was involved with. The patient, a child with a birth deformity from Guadalcanal, needed skull reconstruction. For pre-surgery analysis and brainstorming, the team printed the patient's skull model based on CT-scan data.

"This was one of the first cases where we printed a model to look at the [patient's condition] before the surgery," said D'Urso. "It was a crude model, but I was able to show the patient's mom what was happening. She couldn't really speak English, was scared … obviously it was a major event for her child."

Paul D'Urso, neurosurgeon and founder of Anatomics, discusses using 3D-printed models to communicate with patients and fellow surgeons, at a panel discussion at 3DHEALS 2017.

MORE ➜ rapidreadytech.com/?p=11447

Connecting the Digital Thread

BY JAMIE J. GOOCH

THE RACE IS ON to allow companies to take advantage of the digital transformation disrupting business today, such as access to virtually unlimited computing power to crunch all of the Big Data available from the industrial Internet of Things (IoT), or the mass customization and new business opportunities that knowledge can enable via intelligently automated manufacturing processes and predictive maintenance.

The winners of the race may well be determined by who can put all of those buzzwords together in the most complete virtual process (the longest digital thread) that most closely resembles the real world (the most identical digital twin). In less buzz-worthy parlance, companies need to address both scope and fidelity when adopting new workflows.

At Siemens PLM Connections 2017, which took place in Indianapolis last month, Siemens PLM Software made its case for its approach to digitalization, which reaches far "to the left" of the product development flow, as the company put it, and far to the right into manufacturing, especially when you include its parent company's Manufacturing Operations Management (MOM) and Totally Integrated Automation (TIA) portfolios. Tony Hemmelgarn, president and CEO of Siemens PLM Software, told attendees that this breadth of solutions, including those from newly acquired Mentor Graphics, allows the company to create a more complete digital twin.

"Sometimes the value of the twin is not always so good because the twins aren't that close to each other," Hemmelgarn said. "So really, is there a lot of value in that digital twin if it's set up that way and you're not really representing the full digital twin of the product?"

He said Siemens has spent $6.5 million since 2013 to grow out its portfolio to make a more identical digital twin. That doesn't include the 2012 LMS acquisition, but does include Camstar, CD-adapco, Polarion, Mentor Graphics and others. It has integrated its simulation solutions into a portfolio called Simcenter.

Tony Hemmelgarn, president and CEO of Siemens PLM Software, addresses attendees of Siemens PLM Connections 2017 at the Indiana Convention Center in Indianapolis.

"Together we have an unrivaled digital thread," said Martin O'Brien, VP of Mentor's Integrated Electrical Systems Division, from the stage. "We can feed off each other intellectually. We can create best-in-class, open solutions and finally take a real step forward in creating a true model-based enterprise."

Connecting Virtual and Real Worlds

While Hemmelgarn was quick to point out that the company doesn't silo its products by technology, lifecycle stage or discipline, it does split the stages of digitalization broadly into ideation, realization and utilization sections. In the company's nomenclature, ideation is the up-front stage of product development and utilization includes the feedback loop of data coming back from the enterprise and products in the field.

"Many people miss the middle part," Hemmelgarn said.

MORE ➜ digitaleng.news/de/?p=36982

Solid Edge ST10 Introduced

The latest release of Siemens' Solid Edge software (Solid Edge ST10) features new design technology for working with scanned data and topology optimizations, enhanced fluid flow and heat transfer analysis, and cloud-based collaboration tools, as well as improved technical documentation tools.

Solid Edge ST10's new generative topology optimization, combined with Siemens' Convergent Modeling technology, enables designers to streamline work with imported geometry, says the company.

"Generative can produce great designs, but what if I need to change it?" asked Dan Staples, VP, Mainstream Engineering at Siemens PLM Software, during a presentation of ST10 to the press at the Siemens PLM Connections Americas conference. "3D scanning from points to CAD is the easy part, then you spend days surfacing it. Additive manufacturing is awesome, but you need to design to take advantage of it."

One challenge to the modern design workflow is working with faceted designs and solid models. Convergent Modeling is intended to simplify work with geometry consisting of a combination of surfaces, facets and solids—such as those created by importing third-party files, 3D scanning or through topology optimization.

MORE ➜ digitaleng.news/de/?p=36754

NVIDIA GTC 2017: Welcome to the Holodeck

NVIDIA'S Holodeck project was introduced at the 2017 NVIDIA GTC Conference last month. *Image courtesy of NVIDIA.*

BY KENNETH WONG

DONNING his trademark leather jacket, NVIDIA CEO Jensen Huang took the stage at the San Jose McEnery Convention Center to deliver his keynote to the estimated 7,000 attendees at the annual NVIDIA GTC Conference.

"GTC is where the future is invented; GTC is where we create what others think of as science fiction," Huang said. To prove his statement was not a hyperbole, he proceeded to demonstrate an iconic sci-fi concept, the Holodeck.

In Roddenberry's Star Trek, the Holodeck is a reality simulator built with tangible, solid holograms, a feature of the Federation starships. NVIDIA's Holodeck, on the other hand, is built with pixels and bytes, a virtual reality (VR) environment with photorealistic avatars and interactive physics, powered by the company's VR-ready GPUs.

Though it lacks some of the features dreamed up by the creators of the TV show, NVIDIA's version stands as a tantalizing early prototype, made possible by a convergence of the technologies that have become NVIDIA's core strength.

"We play at the intersection of virtual reality and artificial intelligence," Huang said. "Nothing exemplifies that intersection like the Holodeck."

A Trek into the Holodeck

NVIDIA's Holodeck is a project, not a product, executives were careful to point out. The setup was created using NVIDIA's GameWorks, VRWorks and DesignWorks SDKs (software developer kits).

Huang invited carmaker Christian von Koenigsegg and other participants into the Holodeck, to preview the Koenigsegg Regera, a luxury vehicle powered by a twin-turbine V8 combustion engine.

In many VR setups, when you reach for an object (such as a steering wheel), your hand does not feel its weight. Similarly, when you encounter a barrier (such as a wall), you can still walk through it. NVIDIA's vision is to add a layer of realism by introducing haptic feedback and realistic physics, usually accomplished with gloves in addition to the headset. The Holodeck is still evolving, and NVIDIA is looking to early adopters for ideas.

"The goal is to continue to increase the number of simultaneous users who can participate [in the Holodeck's VR sessions]," said Jason Paul, NVIDIA's GM of VR, in the post-keynote Q&A. "That's the reason we want to bring it out in September, to get the enthusiasts to produce social content. There'll be a massive social media event … First, we want to show people the power of collaboration using good audio, physics and massive models … We expect there to be mods [modified versions created by users]."

Affordable Realism

In some cases, VR-driven training blurs the line between science fiction and real science. Speaking on the panel titled "Beyond Games: How Unreal Engine is Putting the Reality into Virtual Reality," Matthew Noyes, the software lead at the NASA Johnson Space Center's Hybrid Reality Lab, discussed the use of VR and 3D-printed replicas for astronaut training.

"We don't want to just teach the astronauts how to use the tools, but we want them to develop the muscle memory of actually using the tool," said Noyes.

In consumer-class VR setups, the users tend to use joysticks or sensor-equipped handles that symbolically represent a real object, be it a sword, a laser gun or a screwdriver. Though sufficient for entertainment, the same approach may be counterproductive in real training, as the experience is markedly different from how the real device or tool feels in the user's hand.

In NASA's hybrid reality training setup, the virtual environment (for example, a realistically rendered, physically accurate interior of a spacecraft) is delivered to the trainee in an HTC Vive headset.

"A maintenance drill used on the Hubble station for repair costs about $1 million to manufacture. But a 3D-printed facsimile can be created with about $20 worth of plastic materials," Noyes offered a comparison. "The 3D-printed tool is hollow inside, so we can [add artificial weight] to make it weigh as much as the real thing."

The real drill weighs about 10 lbs. on earth. But, to accurately represent how the tool would feel in space, the 3D-printed replica is made to weigh only 2 lbs.

The Volta Leap

This year's GTC is the launch pad for NVIDIA's next-generation GPU, the Tesla Volta V100, representing a significant improvement in GPU architecture to the predecessor Pascal line.

"This is radical limit," Huang said. "I mean, it is at the limit of photolithography. You can't make a chip any bigger than this, because if you do, the transistors will fall on the ground. Every single transistor possible to make by today's physics is crammed into this processor … The fact that this is manufacturable is just an incredible feat."

MORE → digitaleng.news/virtual_desktop/?p=12850

Materialise Summit Expounds on Next 3D Printing Frontier

BY RANDALL NEWTON

FOR 20+ YEARS, most discussions around 3D printing have been about its use in prototyping. By contrast, the presentations and discussions at the recent Materialise World Summit in Brussels were about the disruption of all engineering and manufacturing processes, from initial design consideration to final part or product delivery.

Like the proverbial blind men and the elephant, the main stage presenters all described the new processes of additive manufacturing (AM) from their own specific frame of reference. All saw disruption of processes as the central theme of 3D printing for the next few years. (The terms "additive manufacturing" and "3D printing" were used interchangeably). More than 600 attendees listened to 50+ speakers from leading industrial and medical organizations, including Siemens, BASF, GE, Airbus, GKN, HOYA, Atos, SAP, Safilo, Mayo Clinic, Geisinger Health System, Johnson & Johnson and others. In addition, two panel discussions were organized to allow industry experts to address the future of the technology.

Taking Chemistry into Account

The chemistry viewpoint was one of many frames of reference.

"Additive manufacturing is truly different from classical materials processing," said Volker Hammers, managing director in Germany for chemical giant BASF. "AM means design and process are as important as material properties."

In the past, AM processes were about managing risks through over-engineering and coping with limited materials, Hammers said. "[Today] AM is a journey; the steps from rapid design prototyping to industrial manufacturing of functional parts is strongly underestimated," he said.

Looking ahead, by 2020 Hammers said the state of the art in additive manufacturing will be rapid functional prototyping and small-series production from 3D designs. Small but fast-growing applications in 2020 will include spare parts on demand and plastic parts with integrated functionality (such as built-in circuits.) By 2020 BASF predicts the market for 3D printing materials will be $3 billion. Hammers said BASF also believes 2020 will bring value chain disruptions, performance on the voxel level, in-line chemistry, certified digital manufacturing and a lack of skilled labor.

Pushing Process Innovation

Aeronautics was an early and enthusiastic user of 3D printing technologies. Airbus is now working to move from "advanced prototyping" to serial processes that include "improved process robustness, sensible process monitoring and better surface quality of as-built parts," said Andre Walter, head of Site & Plant for Airbus Bremen. Airbus intends to push AM processes in design and manufacturing. Current design initiatives include developing "manufacturing-friendly" fuselage structure design concepts, and new lightweight designs for existing parts. For manufacturing, current initiatives include development of advanced low-cost processes, new assembly processes and increased production robustness.

There were long breaks between presentation sessions at Materialise World Summit, providing extended opportunities for networking. ***Image courtesy of Materialise.***

The real challenge in process innovation is the creation of a digital supply chain, said Materialise VP of Software Stefaan Matte. Matte used the rapid growth of 3D printing in medicine as an example of innovation that redefines traditional processes. "Designing a surgical guide for a perfect fit doesn't make it a success. The success lies in reaching out to the hospital in the first place," he said.

The Healthcare Angle

Materialise has grown from being a small rapid prototyping service bureau with one 3D printer to a major player in software development, engineering research and one of the world's largest 3D printing service bureaus. One of its largest research tracks is in health care; nearly half of the delegates attending the conference were there for the medical sessions. Attendees in the manufacturing track got introduced to what the other side of the house was discussing in a presentation from Dr. Jonathan Morris, a physician at the world-famous Mayo Clinic in Rochester, MN, and a leading proponent of 3D printing models for surgical preparation.

MORE → rapidreadytech.com/?p=11477

ISC High Performance Preview

THE 32ND High Performance conference, slated for June 18-22 in Frankfurt, Germany, will feature keynote addresses by Dr. Jennifer Tour Chayes, managing director of Microsoft Research New England and Microsoft Research NYC, and Professor Dr. Thomas Sterling, director, Center for Research in Extreme Scale Technologies, Indiana University.

The three-day computing conference is expected to draw more than 3,000 attendees, including researchers, business leaders and scientists, and will feature more than 400 expert speakers and 150 exhibitors.

As part of the conference, ISC High Performance will offer a day for the industrial HPC user community, specifically addressing challenges in the industrial manufacturing, transport and logistics sectors.

The Industrial Day, scheduled for June 20, will be chaired by HPC experts Dr. Alfred Geiger of T-Systems and Dr. Marie-Christine Sawley of Intel Data Center Group. It will focus on three areas:

1. benefits of exascale computing for industrial users,
2. how to purchase HPC infrastructure, and
3. use cases for high performance data analytics, including machine/deep learning, artificial intelligence (AI) and the Internet of Things.

During the Industrial Day, Professor Dr. Norbert Kroll of the German Aerospace Center, Institute of Aerodynamics and Flow Technology, will deliver a keynote address on "High Performance Computational Fluid Dynamics for Future Aircraft Design," focusing on numerical flow simulations.

ISC High Performance will devote June 21 to discuss recent advances in AI based on deep learning technology.

The program is chaired by Dr. Janis Keuper, senior scientist at The Fraunhofer Institute for Industrial Mathematics, and Dr. Damian Borth, director of the deep learning competence center at the German Research Center for Artificial Intelligence.

Two of this year's presentations in the Distinguished Talk series will focus on data analytics in manufacturing and scientific applications. Cybernetics expert, Dr. Sabine Jeschke, who heads the Cybernetics Lab at the RWTH Aachen University, will deliver a talk titled "Robots in Crowds–Robots and Clouds." Her presentation will be followed by one from physicist Kerstin Tackmann, from the German Electron Synchrotron research center, who will discuss big data and machine learning techniques used for the ATLAS experiment at the Large Hadron Collider.

MORE ➜ digitaleng.news/de/?p=36905

Flying on Water

From majestic wooden schooners to today's muscular and high-performance catamarans, the America's Cup charts new waters in technology-driven racing design.

Photo © Harry KK/Land Raver BAR via ACEA.

BY BETH STACKPOLE

ON MAY 26, IN THE CRYSTAL BLUE WATERS of Bermuda's Great Sound, six teams unfurled their wind sails and broke out their collection of hydrofoils, kicking off the month-long competition for the 35th America's Cup, the world's oldest sailing race. Defender Oracle Team USA goes up against teams from New Zealand, France, England, Japan and Sweden. As always, the competition is arduous, but this year's race introduces major rule changes that have upended the boats' design while demanding more rigorous physical performance from crew members.

The storied race got its start in 1851, when the New York Yacht Club's America schooner challenged 15 yachts in Britain's Royal Yacht Squadron to sail between the Isle of Wight and the south coast of England. The U.S. boat finished minutes ahead of its closest rival, setting the stage for one of the longest running sports competitions, which now bears its name. After its first victory, the United States embarked on a 132-year winning streak, defending its trophy 24 times between 1870 and 1980.

During the decades of U.S. domination, the boats did not change much: The schooners gradually morphed into the more recognizable 1930s-era J-Class sailboats, complete with majestic wooden hulls and giant sails and spinnakers. With the exception of the "12 Meter Rule," which called for smaller, more manageable racing boats that cost less and didn't have to be capable of crossing the Atlantic Ocean, regulations governing what teams could do in pursuit of sailing's biggest prize were scant.

"At this point in time, there were very few rules—I'm not even sure the length of boats was a constraint for the teams or even how many crew members," says Alain Houard, marine offshore vice president at Dassault Systèmes, which collaborates with several current America's Cup teams, including Oracle Team USA and Groupama Team France.

Things began to change in 1983, when Australia's Australia II introduced a radically designed winged keel to the 12-meter class boats. To fire back, the U.S. team under Captain Dennis Connor in 1988 designed a lighter class of boat in the form of a multi-hull catamaran, the Stars & Stripes. After some legal challenges, the vessel was okayed by the rules committee and ultimately went on to win that race. Subsequently, this more modern catamaran design set off another series of rule changes—this time, calling for longer, lighter boats with twice as much sail power than the previous 12-meter racers.

The 34th America's Cup, which sailed out of San Francisco Bay in late summer 2013 when the wind speeds were predictable and strong, led to more rule changes that impacted boat designs. The latest class of boats, driven by the winning Oracle Team USA, was dubbed AC72 and encompassed catamarans of up to 86-ft. with giant wing sails. These boats also introduced the concept of hydrofoils, sailing gear that lifts the boats out of the water at speeds over 40 knots (46 mph) and became one of the competition's few areas of design freedom and differentiation.

THEN AND NOW: A painting of the yacht "America" winning the first international race, by Fitz Henry Lane, 1851 (top) and the defending champion's modern catamaran-style lifted out of the water on hydrofoils as its huge wing sail catches the wind. *Photo © Oracle TEAM USA by Sam Greenfield via ACEA.*

Setting a Course for the Cup

Image: rbouwman/iStock

The 35th America's Cup will take place this month on the Great Sound of Bermuda, but teams have been preparing by racing in the Louis Vuitton America's Cup World Series preliminary events that began in 2015. The series regattas were raced in the smaller AC45F-class catamarans that were all designed to the same set of rules and built in the same yard.

At the conclusion of the series in November 2016, Land Rover BAR was on top, followed by defending champion ORACLE TEAM USA as they headed into the qualifiers. The top four teams advance to the Louis Vuitton America's Cup Challenger Playoff semi-finals June 4-8, with the winner facing defending champion ORACLE TEAM USA in the final match, which is scheduled for June 17-18 and June 24-25.

The America's Cup is named after the yacht America, which won the first race in 1851. The United States then embarked on the longest winning streak in the history of sport—132 years—until losing the trophy to Australia II in 1983.

"The competition went from a world where there were almost no rules and everyone could do what they wanted and invent a catamaran from scratch to a world where they have to innovate and invent with a very specific design context," Houard says. Because of their ability to sail at high speeds, the boats were also more at risk, leading to several training accidents that precipitated additional rule expansion to include more safety regulations.

The 35th America's Cup

This latest America's Cup introduces yet another round of significant rule changes—the most dramatic being the reduction in boat size to just 50 ft. Although intermediary races had teams sailing AC62 class boats, at about 60 ft., the teams and committees decided to cut the size back even further in an attempt to cut costs, improve safety and bolster accessibility to other teams. Inspired by the AC45 sport boats that were tested between major races, the America's Cup committee settled on a 48-ft. wing masted foil catamaran as the de facto boat design to race at the Bermuda-bound competition.

"It is clear that if we raced smaller boats in 2017, we could dramatically reduce costs without sacrificing any of the spectacle or the design, engineering and athletic challenge fundamental to the America's Cup," Commercial Commissioner Harvey Schiller was quoted as saying.

The smaller, more muscular AC50 class of boats achieves the same wind speeds as the AC72 class and then some. The hulls, which now play a smaller role in the boat's overall performance because they are rarely in the water, remain tightly controlled under the 40-plus-page design rule document as is the wing, which is a slightly smaller variation of the one found in the AC62 class. Where teams like Oracle and others gain advantage is in the design of more sophisticated control systems and creative foil shapes, which are pushing the boat's performance beyond where anyone expected.

"What really makes these boats special is that they look really similar from a distance, but things are left open in the design of the system," says Aaron Perry, design engineer for Oracle Racing. "Each team has different hydraulic schematics and the foil shapes are all different—those are the deciding factors on the boats."

The hydrofoils (or daggerboards in some sailors' parlance) are designed to minimize drag and boost power, lifting the catamaran hulls out of the water so they appear to fly through the air across waves at speeds approaching 60 mph, nearly double what was possible prior to use of foils. Teams competing in the America's Cup are only allowed to race with two sets of foils; most build one pair geared to heavier winds (usually smaller with less lift and drag potential for higher speeds) and the other set is primed with more size and lift to excel in lighter wind conditions.

"From a design standpoint, that puts a lot of emphasis on the foils themselves and shape of them," Perry explains. "Minute differences seem imperceptible if you're looking at boats as a spectator, but they make a huge difference for how they perform in different ranges of wind speeds."

At Oracle TEAM USA, 3D modeling tools like Dassault's CATIA CAD and SIMULIA simulation packages are instrumental for optimizing these foil shapes as well as for streamlining the process, allowing the team to be agile and adapt to design changes quickly, Perry says. In general, simulation allows the teams to invest or disregard ideas in a more confident way, which is critical given the design constraints coupled with the limitations on time and money, according to Valerio Marra, marketing director at simulation provider COMSOL, who is also a certified U.S. sailing instructor.

"You might have 20 ideas in mind, but you can see only five are good," he explains. "In this case, they are building things that you don't build for everyday use and there aren't millions of them. Simulation enables you to run more tests while doing real-world testing at the same time. It's more important than ever for these guys."

Given that teams are limited in areas where they can

Teams had the chance to collect design data as they trained and competed in qualifiers. *Photo © Austin Wong / ACEA.*

innovate, optimization is key, adds Dassault's Houard. Dassault's 3DEXPERIENCE delivers the 3D modeling, simulation and collaboration capabilities in a single platform, which helps speed the iterative design cycle and brings collaborators from different locations into a common design forum.

In addition to robust use of simulation for foil design, including the study of turbulence and airflow, the Oracle team has leveraged team sponsor BMW's wind tunnel for aerodynamics testing as well as liberal use of 3D printing. 3D printing is a particularly useful tool for daggerboard design because the process allows designers to draw things they couldn't possibility produce with machining processes as well as hollow out parts for optimal aerodynamics, explains Perry. "It's so much faster to produce this way instead of sending it out to a machining operation, which could take weeks," he says. "It compresses the time it takes to get from a finished design to getting parts out on the boat."

Oracle TEAM USA's boat for the 35th America's Cup is also equipped with hundreds of sensors and Bluetooth, fiber optics and Wi-Fi connectivity capabilities, and every sailor on the boat is outfitted with a wearable to track heart rate and other bio signals in real time to optimize their performance given that the race requires far more athleticism than past sailing competitions. In total, the boat generates gigabytes of real-time data that will be leveraged for a variety of purposes, from weather modeling to course planning and subsequent boat design changes.

"The tools, the computing power, the amount of data we're collecting in the process—everything has ramped up to the point where we are able to predict much more accurately what will happen on the water than what was possible before," says Perry, who counts the upcoming 35th America's Cup as his sixth major race. "Everything has advanced to a level that this Cup feels different than previous ones." **DE**

Beth Stackpole *is a contributing editor to* DE. *You can reach her at beth@digitaleng.news.*

INFO → America's Cup: AmericasCup.com

→ COMSOL: COMSOL.com

→ Dassault Systèmes: 3DS.com

→ Oracle Racing: OracleRacing.com

For more information on this topic, visit digitaleng.news

It Takes Technology and Teamwork to **Win** the Race

How America's Cup defenders and challengers integrate design, simulation, optimization, 3D printing, data analysis and high-performance computing technology for any advantage.

BY KENNETH WONG

The Land Rover BAR team uses Python scripts in Siemens NX to tie in simulation, design and automatic shape generation. *Image courtesy of Siemens PLM Software*.

CALLING THE AMERICA'S CUP a boat race is a bit of a misnomer. A closer examination of the competing vessels reveals they resemble planes more than boats. For the most part, they fly over the water using wing-like hydrofoils, remaining largely airborne to minimize drag.

The rules allow the competing teams to begin testing their AC50 (America's Cup) race boats in Bermuda 150 days prior to the event. But long before they touch the azure waters of the Great Sound in Bermuda, many of these boats have already set sail hundreds of times in oceans of bits and pixels, having been tested in the rough winds and waters constructed from partial differential equations in computational fluid dynamic (CFD) programs.

The Rise of Hydrofoils

In the 35th America's Cup presented by Louis Vuitton, the defender Team Oracle USA faces five worthy opponents: Artemis Racing, including Olympic champions; Emirates Team New Zealand; Groupama Team France; Land Rover BAR, led by Sir Ben Ainslie (previously with the Oracle team); and SoftBank Team Japan, led by Dean Barker (previously with Team New Zealand).

The teams design and build their own America's Cup Class (ACC) boats—about 15m (nearly 50 ft.) in length, built according to the Cup's official specifications. A common characteristic of the boats is the use of wing-like hydrofoils, a recent development in the sailing world.

"The boats are aiming to be foiling right around the race course," observes Russell Coutts, America's Cup CEO. "The boats today are faster than they were three years ago, and they are smaller boats ... Where we used to watch races that took an hour and a half, we're now seeing a race last around 22 minutes with essentially the same number of maneuvers."

"At high speed, drag and seakeeping become big issues

Photo by Ricardo Pinto via ACEA.

aboard any vessel, particularly offshore monohulls ... Rising above the water's surface [a mode of sailing possible with foiling] not only reduces drag, but might help to reduce structural risks and make handling at speed easier," points out Matthew Sheahan in his July 2015 *Yachting World* feature, "The foiling phenomenon: how sailing boats got up on foils to go ever faster."

The design teams involved in the America's Cup spend a good part of their time figuring out the best foil shape,

> **"We've got to be able to figure out how much higher we can push things before they'll break, which is maximizing performance and boat speed."**
>
> ***– Marty Yates, Emirate Team New Zealand***

analyzing the tradeoffs between lift and drag, and studying the performance of the prototype boats during the test period. According to the race rules, testing in the waters at the site is only available for a small window of time. Therefore, the teams rely on a range of digital design and simulation tools to refine and perfect the performance of their boats in advance.

The Quest for the Golden Ratio

First founded in 2000, Oracle Team USA wrestled the trophy away from the Swiss team Alinghi in the 33rd America's Cup in 2010 (Valencia, Spain) using a wing sail design, and emerged victorious once more in the 34th America's Cup in 2013 (San Francisco). With two past victories in tow, the Oracle Team heads to Bermuda this year to defend its title.

"For the most part, the boat is sailing on its hydrofoils, which are essentially wings," says Len Imas, CFD specialist from Team Oracle's design team. "A normal sailing vessel keeps its hull in the water and is driven by hydrostatics—basically, Archimedes' principles. On the other hand, the race boats in the America's Cup are supported by their wing-like foils that generate lift."

Because the boats mimic airplanes with the use of hydrofoils, they also face many of the same aerodynamics challenges encountered by airplanes. "Once you put underwater wings on a boat, you have to worry about how you control it," says Hal Youngren, aerodynamics/hydrodynamics engineer from Team Oracle's design team. "Our rudder—an important feature of the boat—acts like a tail does on an airplane to stabilize the boat."

If you can think of the boat's rudder as the tail of an airplane, you can think of the hydrofoils as its wings. "The catamarans are popular in this race because they can fly above the water using hydrofoils," says Aurelien Miller from Artemis Racing's engineering team. "When the boat is flying one meter above the water, the only points of contact between the boat and the water are those hydrofoils. The foils are quite similar to airplane wings."

But sailing on wings in water is not the same as flying through the air. "The flying stability is a big challenge especially in the daggerboard development," says Andrea Vergombello from the design team of Groupama France. "You can obtain the best board in terms of performance, but you need to respect some stability criteria in order to create a foil that's also easy to handle. The balance between pure performance and stability require lots of work and experience, especially on the water."

Yachting World's Sheahan points out: "While foiling clearly appears to reduce the wave-making drag considerably, there is no free lunch. Lift and drag go hand in hand and what happens beneath the surface can sometimes wipe out any benefit above. For example, tilting a foil at a large angle of attack may create lift, but there will often be a large amount of drag, too."

America's Cup boat design engineers and simulation analysts need to focus on both air and water. "We look at the areas of the boat exposed to wind and water, so hydrodynamic and aerodynamic are equally important for us," says Rodrigo Azcueta, a member of Land Rover BAR's concept team. "As water and air flow around the body of the boat, it generates forces. We're interested particularly in the resistance that creates drag, and the forces that create lift. The lift-to-drag ratio is what we're trying to optimize."

> **“When we build a prototype boat and test it, we can use sensors to measure the pressure on the components, the deformation in the fiber parts and so on.”**
> ***– Rodrigo Azcueta, Land Rover BAR***

The Boiling Point

All the AC50 race boats are equipped with hydrofoils, so they must confront cavitation or “cold boiling,” associated with rapid pressure changes in liquids. Cavitation occurs at high speeds and causes formation of small vapor cavities or bubbles.

“Cavitation prevents the boat from going faster,” explains Azcueta. “When we build a prototype boat and test it, we can use sensors to measure the pressure on the components, the deformation in the fiber parts and so on. We can also have cameras pointed at the components so we can observe the cavitation, to see if it appears.”

Emirates Team New Zealand also makes use of sensors to collect data and improve boat design. “There are sensors all around the boat looking at different aspects, whether it’s the loads on the rudders, for instance, or the daggerboards,” says Marty Yates, IT manager for the Emirates Team New Zealand in a video produced by HP, an official supplier of the team. “We get hundreds of data points coming off per second and then that’s all analyzed in terms of the boat speed, the direction, the strains … We’ve got to be able to figure out how much higher we can push things before they’ll break, which is maximizing performance and boat speed.”

The team uses an HP Z840 workstation as a dedicated SQL server to handle the number crunching, mobile HP workstations for design and another HP Z840 for ANSYS simulation analysis.

Even though the test sailing period is limited, the teams have the option to build scale models and prototype boats to test elsewhere, but that option is also limited by the cost involved. “Building boats and testing them is very time consuming,” says Land Rover BAR’s Azcueta. “We rely on digital simulation to shorten the design process.”

“Whereas you can put an airplane in a wind tunnel or a boat in a towing tank, you can’t really do that to understand a catamaran, because it’s a complex interaction of wind, water, hydrodynamics, and aerodynamics,” explains Stephen Ferguson, Siemens PLM Software’s marketing director. “Many of the teams in America’s Cup use CFD for aerodynamic and hydrodynamic tuning.”

Ferguson was previously employed by CD-adapco, makers of the STAR-CCM+ simulation software suite. The software is known for robust CFD tools and features. Last year, Siemens PLM Software acquired CD-adapco, making STAR-CCM+ part of its Simcenter portfolio.

“Our main challenge in simulation is cavitation and fluid-structure interaction (FSI),” says Azcueta. “The physics involved is very complex.” The complexity of the simulation comes from the need to employ not just one type of physics but multiple types. Simulating the waves’ potentially damaging impact on a boat’s structure, for example, involves not just fluid dynamics but structural mechanics. Such simulation calls for multiphysics solvers or code-coupling, enabled by a limited number of simulation packages.

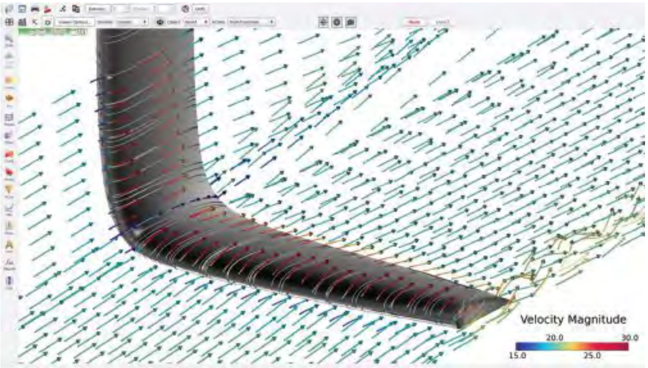
Automated Shapes, Scripted Meshes

On the day of the race, speed is the deciding factor. But long before the race, when the design teams are subjecting the 3D digital models of their boats to CFD tests, a different kind of speed offers an advantage—the speed with which engineers can study and evaluate dozens or hundreds of designs simultaneously.

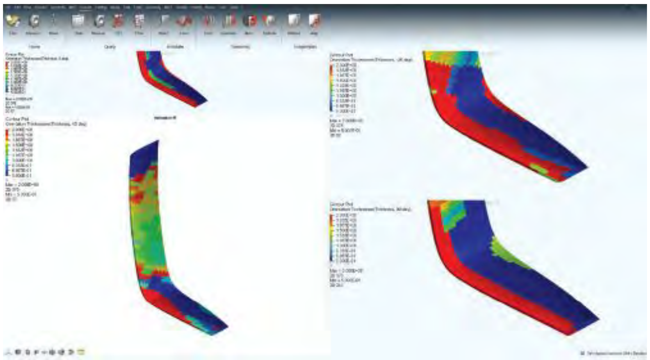
“We look at a very large number of designs,” says Land Rover BAR’s Azcueta. “We generate parametric models of the critical components, like the wing, the daggerboard and the foils. The design parameters like lengths and thicknesses vary. Then we generate hundreds of shapes and run hundreds of simultaneous simulations. We send them all at once to the high performance computing (HPC) queue. In a few days, we get the results back when all these simulations are finished. That’s when we usually build a force model” to study the effects of different forces on the boat’s components.

Land Rover BAR uses ESTECO’s modeFRONTIER software to automate the foil design process. The team uses Siemens NX to design the shape of the boat, and STAR-CCM+ to run CFD simulation on the design.

“We added support for Python scripts in NX,” says Paul Brown, Siemens PLM’s senior marketing director. “So inside



An AcuSolve computational fluid dynamics analysis of flows around a daggerboard is visualized in AcuFieldView. *Image courtesy of Altair*.



OptiStruct was used by Artemis Racing to perform structural analysis on a laminated composite daggerboard. *Image courtesy of Altair*.

NX, engineers can tie simulation, design and automatic shape generation. That gives a team like Land Rover BAR the ability to quickly go through lots of iterations, evaluate them."

"The important thing about this process is, it's entirely automated, so basically the engineers can change the design parameters in response to the CFD results they see to run another set of simulations," adds Ferguson.

The engineering team of Artemis Racing turns to Altair Engineering, known for its OptiStruct solver and HyperWorks computer-aided engineering (CAE) software suite. HyperMesh, part of the HyperWorks bundle, is known for accurate, efficient meshing, a critical pre-processing requirement in finite element analysis (FEA).

"If we were looking only at the structure, we could run the simulation on a single computer," says Artemis Racing's Miller. "But we were also coupling structure simulation with fluid calculation. So we ran the jobs on our HPC server. Usually we use around 20 cores for linear calculations, 300 for nonlinear calculations."

"There's an enormous amount of tradeoffs among structure, control and hydrodynamics."
– Hal Youngren, Team Oracle

The Artemis team is building its foils with composite materials, which offer certain structural advantages. But the decision also puts a burden on the simulation software. "If it were metal, we could apply tetrahedral meshes. But meshing composite design is harder. We used hexahedral meshes, which require a lot more care and attention," says Miller. "We built solid element models of the hydrofoil. They're each roughly between 500,000 and 1 million elements. We were looking at about five different designs at the same time. With the use of HyperMesh, we cut the preparation time by half."

Every team raced against time and the limits of physics in designing their boats before they could race one another.

"Computer technology in the America's Cup is one of the main factors, especially now in the 35th America's Cup where we're heading toward the most technologically advanced boats ever seen," says Yates from Emirates Team New Zealand.

Emirates Team New Zealand uses SOLIDWORKS and AutoCAD for design, then turns to ANSYS multiphysics tools to simulate how structural composite components will interact with the air and water under different circumstances. ANSYS DesignXplorer, integrated into ANSYS Workbench, is used to explore and optimize the designs.

"The aero- and hydrodynamic components of our official race boat are the results of several optimization steps, including performance reliability structure criteria and weight reduction," says Groupama France's Vergombello. Groupama uses Dassault Systèmes' Designed for Sea industry solution to create the general shape of the catamaran. Designed for Sea is based in Dassault Systèmes' 3DEXPERIENCE platform. It targets naval architects, engineers and designers in shipyards. As such, it includes tools to help ensure compliance with industry regulations and classification standards.

Groupama uses Rhino, a surface-modeling program, and Grasshopper, a plug-in to Rhino, to design the boat's foil. To manage the optimization process, it uses ESTECO's modeFRONTIER software. "In the first period, modeFRONTIER software supported our 2D section optimization, both for the daggerboard and the rudder ... We use it to find the best way to optimize a 2D foil cross-section, starting from working conditions and constraints. During the second stage in the campaign, other team members started using modeFRONTIER to optimize the daggerboard's 3D shape," says Vergombello.

Team Oracle has a multistage process. "We use the CAD software to generate the shape of the foil and other parts of the boat—like wings and hulls," says Team Oracle's Imas. "Then we use a broad set of simulation tools to progressively improve the design in subsequent iterations."

The five challengers to Team Oracle USA. *Photo by Ricardo Pinto via ACEA.*

One of the tools the Oracle team is using is Pointwise, a software program for generating CFD mesh models. "Pointwise's advantage is that it can be scripted," says Youngren. "It can take our CAD geometry, cut it at water surface, re-mesh it and then dump it into our analysis tools. It's basically automated using the scripting language called Glyph that is built into Pointwise."

"The aero- and hydrodynamic components of our official race boat are the results of several optimization steps, including performance, reliability, structure criteria and weight reduction."
— Andrea Vergombello, Groupama France

Different Assumptions, Different Bets

Using time-tested fluid dynamics and structural mechanics principles, simulation and optimization software programs provide answers based on the users' inputs and constraints. For example, a simulation package can calculate the stress distribution on the surface of the hydrofoil based on the forces specified by the user. Similarly, an optimization program can suggest the best geometry for the hydrofoil based on the loads and the weight limits specified by the users. Therefore, the gamble in the foil design may ultimately come down to the assumptions each team makes about the sailing conditions, which translate to the parameters they feed into the simulation software.

"It turns out, in Bermuda, the range of possible sailing conditions is quite a bit larger than they were at the site of the last America's Cup [the San Francisco Bay]," notes Youngren. "Most of our hydrodynamic design efforts are split into designing for high-speed conditions (for stronger wind), and lower speed conditions (for lighter winds and slower sailing). You need to look at both because it's very difficult to use a light-air foil to sail in high-speed conditions, and vice versa."

Imas says many questions come into play during design and optimization. "Do you put more weight on designing for the heavier winds? Do you design for best sailing in lighter, intermediate winds? Or do you try to account for both equally with the same foil design? These assumptions and design goals push you down a specific design path," he says.

Encoding the Wind's Power and Reducing Weight

The best types of simulation are those driven by real-world experience and data, obtained from physical tests and past records. The racing teams in the America's Cup have a narrow window to test their AC50 boats at the race site; therefore, collecting data during those test runs is all the more critical for subsequent design refinements.

Land Rover BAR turned to Renishaw, a recognized name in the metrology industry, to produce a bespoke magnetic encoder. According to Renishaw, the encoder system is "designed for integration into hydraulic, pneumatic and electromechanical actuators as a feedback element for position or velocity ... The position encoders were installed on the control surfaces of both the wing (flaps) and the port and starboard rudders."

The encoders help measure the degree of camber, or curvature, in each of the wing sections during the boat's operation. "In lighter wind, you have more camber; in stronger wind, you reduce camber because you effectively have too much power and you're trying to spill some of it," says Paul Campbell-James, Land Rover BAR's wing trimmer. "The Renishaw

In addition to cross-discipline engineering technology working together, everyone on each America's Cup team must work together for victory. *Photo by Ricardo Pinto/via ACEA.*

encoders tell me the ratio between the different levels. I'll use that to determine the best twist profile going up the wing to give the boat maximum speed."

Renishaw has also manufactured several hydraulics parts for Land Rover BAR using additive manufacturing (AM), which helped reduce weight. For example, the weight in a new AM manifold design was reduced by 60%, with an increase in performance efficiency of better than 20%.

The Choreography of Victory

On the day of the race, the racing teams confront one of the big unknowns that can change their fate—the weather. "The night before the race, we look at weather forecast. Based on that forecast, we tune certain components, the same way a race car team would tune their vehicle," Land Rover BAR's Azcueta says. "The wing and the boat are fixed, but we have different foils to choose from, and we can make small adjustments."

Having the best boat or foil design may provide an advantage, but it alone cannot promise victory. "You also need the best helmsman, wing trimmer and crew to control and maneuver the boat," says Team Oracle's Youngren. "Sailing one of these AC50s is more like a choreographed dance—everyone on board has to move very precisely."

The choreography also extends to the design work that takes place months or years prior to the race. In the simulation and analysis sessions before the physical prototyping, people with different backgrounds have to come together. It's highly improbable that a design team could find a single expert who understands structural mechanics, aerodynamics and hydrodynamics. In most cases, experts from these different disciplines have to work together to build and refine the boat.

"My background is in aerodynamics and aerospace," Youngren says. "My colleague Len Imas's background is in CFD. We have a fairly small group of hydrodynamicists, but we work closely with designers whose strength is in control systems design or structural engineering. There's an enormous amount of tradeoffs among structure, control and hydrodynamics."

> **"We built solid element models of the hydrofoil. They're each roughly between 500,000 and 1 million elements. We were looking at about five different designs at the same time."**
> ***– Aurelien Miller, Artemis Racing***

During the testing period and the race, each team observes the others. They take note of the rivals' design ideas, along with the advantages and disadvantages noticeable on the water. They then incorporate these insights into their own boats' designs, germinating ideas for the next America's Cup. Thus, with each race, a better, faster generation of catamarans is engineered. **DE**

Kenneth Wong *is* DE*'s resident blogger and senior editor. Email him at de-editors@digitaleng.news or share your thoughts on this article at digitaleng.news/facebook.*

INFO ➜ **Altair Engineering:** Altair.com

➜ **ANSYS:** ANSYS.com

➜ **Dassault Systèmes:** 3ds.com

➜ **ESTECO:** Esteco.com

➜ **Grasshopper:** Grasshopper3d.com

➜ **HP:** HP.com

➜ **Pointwise:** Pointwise.com

➜ **Renishaw:** Renishaw.com

➜ **Rhino:** Rhino3d.com

➜ **Siemens PLM Software:** Siemens.com/PLM

AMERICA'S CUP BACKGROUND

- **35th America's Cup:** AmericasCup.com
- **Artemis Racing:** Artemis-Racing.AmericasCup.com
- **Emirates Team New Zealand:** Emirates-Team-New-Zealand.AmericasCup.com
- **Groupama Team France:** GroupamaTeamFrance.AmericasCup.com
- **Land Rover Ben Ainslie Racing (BAR):** Land-Rover-Bar.AmericasCup.com
- **SoftBank Team Japan:** SoftBank-Team-Japan.AmericasCup.com
- **Team Oracle USA:** Oracle-Team-USA.AmericasCup.com
- ***Yachting World* article:** YachtingWorld.com/special-reports/the-foiling-phenomenon-66269

For more information on this topic, visit digitaleng.news.

Happy Birthday, AutoCAD

After 35 years, AutoCAD is still the world's leading CAD program.

BY DAVID COHN

IN LATE MARCH, Autodesk unveiled AutoCAD 2018, the 32nd release of its flagship product. The announcement came exactly 35 years and two days after the company first exhibited INTERACT, a program that within a few months would forever become known as AutoCAD. It has certainly been an interesting 35 years.

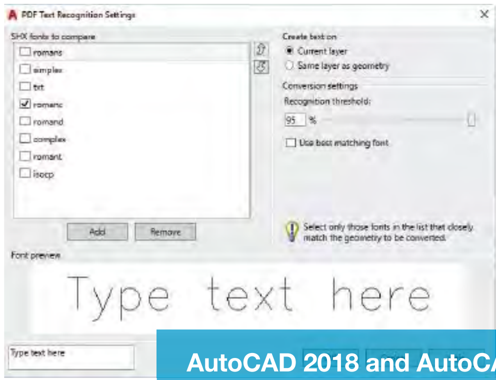
Last year, AutoCAD 2017 set the stage for Autodesk's move away from perpetual licensing to a subscription model in which you rent the software on a monthly, quarterly, annual or multi-year basis. AutoCAD 2018 sets the stage for future development. The program uses a new file format—the first time the DWG format has changed since the 2013 release. The change provides a foundation on which to develop this and future releases.

Improved PDF and Text Capabilities

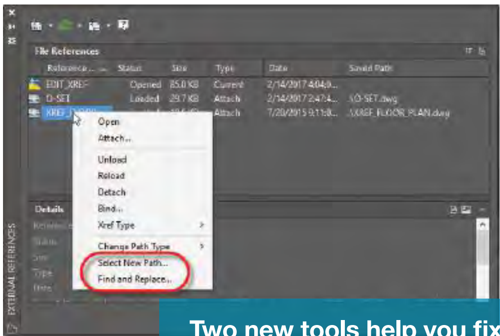
Improvements to AutoCAD's PDF capabilities lead the list of new features. PDF files are the most common file format used when exchanging design information between members of the design team and others. AutoCAD 2017 introduced the ability to import PDF files. Before then, you could attach a PDF as an underlay and then manually recreate the depicted geometry. The PDFIMPORT command added last year enabled users to import actual PDF geometry as 2D AutoCAD lines, arcs and circles. AutoCAD 2017 also could recognize TrueType text and images.

But because Adobe's PDF format doesn't recognize AutoCAD SHX fonts, text that had originally been defined with SHX fonts was stored in the PDF file as geometry. When that PDF file was subsequently imported into a DWG file, the original SHX text was imported as geometry, not text.

AutoCAD 2018 provides a new text recognition tool that enables you to select imported PDF geometry representing text and convert it into actual AutoCAD text objects. The new SHX recognition tool analyzes selected geometry, compares it with characters in SHX fonts you specify, and converts it into text. A settings dialog help you manage which SHX fonts to compare against selected text. The most common SHX fonts are listed by default and you are able to add and remove fonts based on your needs. The program compares each of the selected fonts in order until one is found that matches the selected text within the specified recognition threshold. Although this tool was actually added to the 2017.1 release, a new option lets the program use the best-matching font, ensuring that AutoCAD compares the text with all of the selected fonts and then chooses the best match.



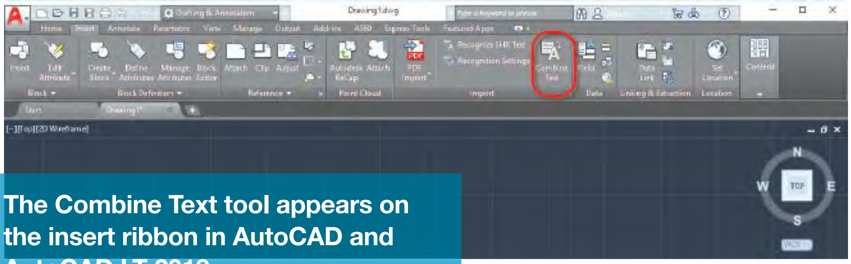
AutoCAD 2018 and AutoCAD LT 2018 now enable you to easily control settings when converting SHX text geometry back into actual text.



Two new tools help you fix things when links to external references become broken.

Other PDF improvements correct orientation problems with rotated TrueType text so that the program no longer creates upside-down text.

Another new tool lets you convert single-line text into Mtext and combine multiple individual text objects into one multiline text object. This can be particularly useful after recognizing and converting SHX text from an imported PDF file. Although the TXT2MTXT tool had been available in AutoCAD previously as an Express Tool, it now also shows up on the inert ribbon in AutoCAD and AutoCAD LT. The new version of this tool lets you select Mtext objects in addition to text. Character codes translate correctly between Text and Mtext, justification is properly in-



The Combine Text tool appears on the insert ribbon in AutoCAD and AutoCAD LT 2018.

ferred based on the positioning of text objects (instead of always defaulting to left-justification) and numbered and lettered list formatting is inferred when the word-wrap text checkbox is selected. Additionally, there is a new option that allows you to force uniform line spacing or maintain existing line spacing.

Improved Control Over External References

When you attach an Xref in AutoCAD 2018, the default path type is now set to Relative path instead of Full path, although you can control this by changing a new system variable. In previous releases of AutoCAD, you could not assign a relative path to a reference file if the host drawing had not yet been saved. In AutoCAD 2018, you can. The reference file shows up in the External References palette with an asterisk preceding the full path until the host drawing has been saved.

If the current drawing includes relative references and you save it to a different location, the program now prompts you to update the relative path. In the External References palette, when you right-click on a reference file that is not found, the program provides two new options. Select New Path allows you to browse to a new location for a missing reference and then asks if you would like to apply the same path to other missing references. Find and Replace locates all references that use a specified path for all of the references you selected and replaces all occurrences of that path with a new path that you specify. In addition, when you choose Change Path Type from the right-click or toolbar menus for a reference in the External References palette, the current path type is grayed out, helping you identify the type of path used for the selected reference.

A host of other improvements to external references should help avoid broken references. If you do open a drawing with external references that aren't found, the program now shows the number of references that are not found rather than missing. You can then immediately open the External References palette and use the new tools to restore the missing references.

Other Notable Improvements

Those working in large drawings will welcome a subtle change to the program's object selection. You can now begin a selection window in one part of your drawing and then pan and zoom to another part of the drawing while maintaining the selection.

Linetype gap behavior has also been enhanced to support complex and DGN linetypes. And, this feature now works with all objects, such as wide polylines and splines: You can select any linetype or snap to them by picking on gaps between the geometry. You also can easily add the Layer Control drop-down to the Quick Access toolbar by selecting it in the toolbar menu rather than opening the program's complex customization dialog.

These are the most obvious new features, but other improvements in the new release are more subtle. As a result of the new file format, save performance is significantly improved. AutoCAD 2018 also fully supports 4K displays. When working on a high-resolution display, users may want to open the Graphic Performance dialog to turn off smooth line display while keeping the high quality geometry option enabled. These have now been split into two separate settings. Lines displayed on screen consist of individual dots or pixels. When smooth line display is enabled, the program performs anti-aliasing, adding additional pixels adjacent to those forming the line, so that the line appears smoother. Although this improves image quality, it is likely unnecessary at higher resolutions, and the additional dots can affect performance.

After 35 years, AutoCAD remains the world's leading CAD program. The improvements made to this, its 32nd release, set the stage for many years to come. **DE**

David Cohn *has been using AutoCAD for more than 34 years and is the author of over a dozen books on AutoCAD. As senior content manager at 4D Technologies, he creates the CADLearning courses for AutoCAD and AutoCAD LT (cadlearning.com). He is a contributing editor to* Digital Engineering, *and also does consulting and technical writing from his home in Bellingham, WA. You can contact him at david@dscohn.com or visit dscohn.com.*

INFO → Autodesk, Inc.: Autodesk.com

AutoCAD 2018 and AutoCAD LT 2018 are only available by subscription. Customers can trade in R14 through 2016 perpetual licenses for discounts of up to 30% on a three-year subscription.

AutoCAD 2018

Monthly: $185 1 Year: $1,470 2 Years: $2,795 3 Years: $3,970

3 Years (with trade-in of perpetual license): $2,779

AutoCAD LT 2018

Monthly: $50 1 Year: $380 2 Years: $720 3 Years: $1,025

3 Years (with trade-in of perpetual license): $717.50

SYSTEM REQUIREMENTS

- **Operating System:** Windows 10, 8.1, or 7; 64-bit or 32-bit
- **CPU:** 1GHz or faster 32-bit (x86) or 64-bit (x64) processor
- **Memory:** 2GB (4GB recommended)
- **Disk Space:** 6GB for installation (4GB for AutoCAD LT)
- **Display:** 1360x768 (1600x1050 or higher recommended) with True Color (DirectX 9 or DirectX 11 compliant card recommended)
- **Other:** Microsoft Internet Explorer 11 or later web browser

Topology Optimization Part 1

Gain insight as to what controls can be exerted on the process to increase relevance to design goals.

BY TONY ABBEY

***Editor's Note:** Tony Abbey teaches live NAFEMS FEA classes in the United States, Europe and Asia. He also teaches NAFEMS e-learning classes globally. Contact him at tony.abbey@nafems.org for details.*

IN PARTS 1 AND 2 of this article I dive deeper into the background of topology optimization and attempt to give insight into what controls we can exert on the process to improve the relevance to our design goals.

Fig. 1 shows a typical topology optimization analysis, based on the geometry, materials and loading definition given in the GE/GRABCAD challenge.[1,2] *Disclaimer: My version is not a contender.*

I do recommend trying the GE/GRABCAD challenge as your own benchmarking exercise. The specification, initial geometry and full set of 638(!) results are available online.[1] Various assessment papers also have been written that critique the winning designs from structural and manufacturing perspectives.

The basic idea behind topology optimization is to define a design space and mesh that with a regular array of elements. In some cases, this will be an arbitrary 3D or 2D space; in other cases, as shown in Fig. 1(a), the mesh will follow an initial scheme. We will look at the implications of this distinction in part 2. The boundary conditions and loading are defined as normal in a finite element analysis (FEA) solution, and analysis starts with the full design space as shown in Fig. 1(b). Material is progressively removed using a target volume reduction until a final iteration is completed, as shown in Fig. 1(c). The final design is assumed to be optimized to a defined level of efficiency at that target volume.

Topology Optimization Methods

Fig. 2 shows the general concept schematically. Element i is a typical element within the design space.

An initial finite element analysis of this component will give a distribution of internal stress and deflection. Topology optimization seeks to improve the efficiency of the configuration by removing material based on these FEA responses. Intuitively, we could do the job manually by starting to remove material that had a very low stress level. This type of approach is called an optimality criteria method. It is based on a heuristic idea—something that looks like a good approach from an engineering point of view. A formal implementation is called fully stressed design (FSD). It is easy to implement and computationally cheap. Unfortunately, FSD does not work so well with multiple load paths, as found in most typical structures. Attempting to set all regions of the structure to very high stresses is not a realistic goal. FSD is sometimes used in a mixed strategy in combination with more sophisticated optimization objectives, such as minimizing strain energy.

Minimizing the strain energy also can be described as minimizing the com-

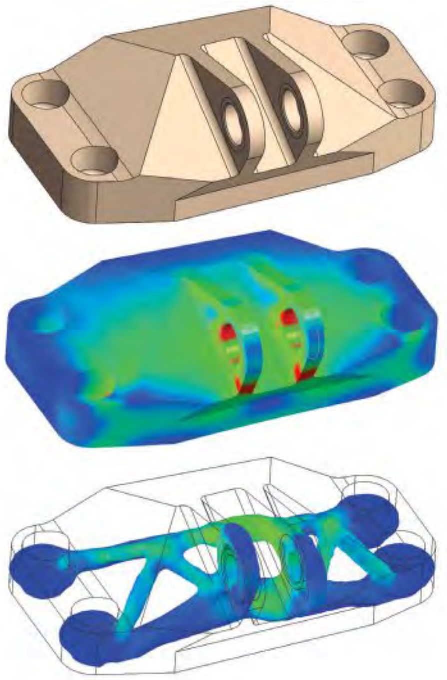


FIG. 1: (a) *top*, initial design space. (b) *middle*, initial analysis. (c) *bottom*, final analysis.

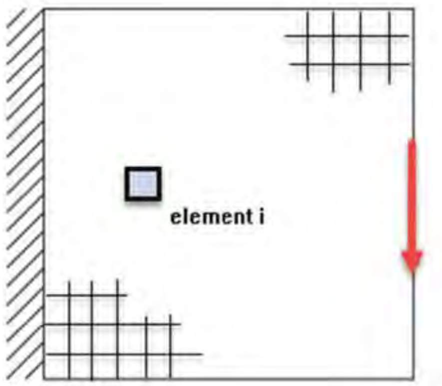


FIG. 2: A schematic of FEA topology optimization.

pliance. Compliance is defined as the distributed force multiplied by displacement summation. Anything that minimizes the displacement distribution will maximize stiffness. Minimizing strain energy, maximizing stiffness or minimizing compliance are very closely linked concepts. All of these are global targets or objectives in that they are applied to the overall structure.

So how do we remove material from the mesh? In an FEA analysis it is efficient to keep the mesh constant throughout a series of model configuration changes. The assembly of element stiffness matrices into a system stiffness matrix at each iteration is just a scaling process on local element stiffness values. Elements aren't deleted, but instead scaled down toward a small stiffness limit. The stiffness terms don't quite go to 0.0, as this would give singularities.

Historically there have been two main approaches: The evolutionary methods (evolutionary structural organization [ESO] and bidirectional ESO [BESO]) aim to provide a "hard element kill" approach. This means element i is either present, with full stiffness, or effectively eliminated, with a very low stiffness. Alternatively, the penalty-driven method (SIMP) is described as a "soft kill" method and allows a gradation of stiffness range between the full value and a very low value. Other methods are available, but I am going to focus on the SIMP method in this article.

The SIMP Method

The full title of the SIMP method is "solid isotropic microstructure with penalization." That is a bit of a mouthful, but we will attempt to break it down. The term "microstructure" is included in the title because early work looked at developing material systems that were porous and made up of voids and material in various distributions. Using this approach, anisotropic materials such as foams, lattices and composites could be defined. This work has evolved in many interesting directions, including microstructure forms for lattice-type structures in additive manufacturing. However, if the requirement is to work with conventional materials, then "solid isotropic" representation is required.

As mentioned, stiffness will be allowed to vary throughout the mesh, between initial value and close to 0.0. The design variables are defined per element, not as the stiffness, but as a normalized value for density. The stiffness is assumed to be directly scaled by the density value. The term "density" is a little confusing because the design variables are normalized values between 1.0 and 0.0.

So where does the "penalization" term originate? If a structure could develop any value of density between 1.0 (black) and 0.0 (white), we would get very large areas of "gray" material. Gray areas are not physically meaningful for a solid isotropic material. We need to cluster distributions of density toward 1.0 representing the parent material, or 0.0 representing a void. The approach taken in SIMP is to penalize any density that is in the gray region. Fig. 3 shows the penalty function used. The density is adjusted from its nominal value with a bias toward the extremes of 0.0 or 1.0. The order of the penalty function, P, is often provided as a user control. Setting P higher than 1 will give more realistic structures with less gray. Somewhere between 2 and 4 is typically used—but it is worth experimenting to see the effect.

Inherently there will always be a blurred region of density, and hence stiffness, in the SIMP method. The method does not focus on traditional boundary region features, which develop stress concentrations. The structural and, hence, stress representation is not exact at a boundary. Local stresses should be viewed as a "smeared" and averaged general indication. Similarly, the actual geometric boundary is not exactly defined. In the second part of this article I will look at these implications for stress as both a constraint and as an objective function—a possible alternative to compliance.

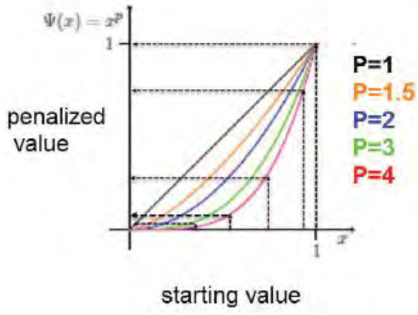


FIG. 3: The penalty applied to intermediate densities.

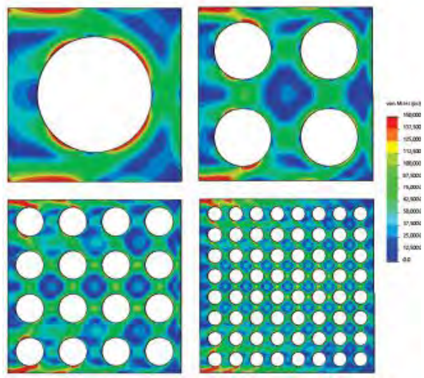


FIG. 4: Component with increasing number of holes and constant volume.

holes	Area (ins^2)	Perimeter (ins)	Deflection (ins)	Compliance (lbf in)
1	0.65	2.09	-0.0098141	9.8141
4	0.65	4.19	-0.0078273	7.8273
16	0.65	8.38	-0.0074661	7.4661
64	0.65	16.76	-0.0072699	7.2699

FIG. 5: Variation of perimeter deflection and compliance with number of holes.

Mesh Dependency

Fig. 4 shows a series of models that have an increasing number of holes within them, running from 1 to 64. In each model the left-hand edge is fixed and the right-hand edge is loaded vertically, giving a shearing type response. The volume of material in each model remains the same at 65% of the volume without any holes. The resultant deflections are shown in Fig. 5.

It is interesting to note that as more holes are included, the right-hand edge deflection reduces. A plot

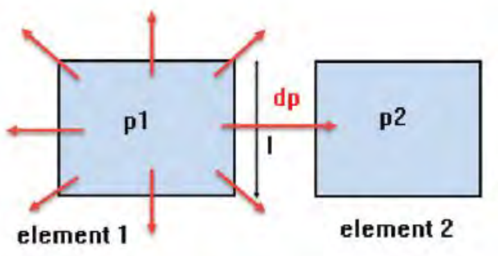


FIG. 6: Perimeter control methodology.

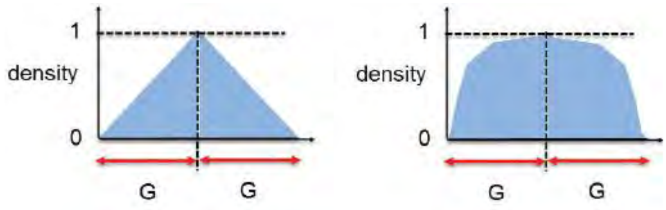


FIG. 7: (a) *left*, density gradient control before penalty application. (b) *right*, after application.

of deflection against number of holes would show a clear tendency to converge to a finite deflection value. This shows that, in the limit, we can get the stiffest possible structure at 65% of the volume by having a distribution of very tiny holes. In fact, the solution is telling us that we should be really using foam made of the parent material! If we are trying to design a structure using isotropic material then this is clearly a nonsensical result. Fig. 5 also shows that as the number of holes increases, the total perimeter is increasing. We also see that compliance is decreasing. Compliance is calculated as the applied force multiplied by the resultant deflection. Compliance is one of the most popular measures of efficiency of a structure in topology optimization.

Mesh dependency, with a tendency toward a high level of porosity, is one of the attributes of topology optimization discovered early on. For a specific optimization problem, given a target reduction in volume, the solution will depend on the element size within the mesh. A very fine mesh can drive toward a foam-like "filigree" or "fibrous" configuration. The last two typically have many very thin strands of material. A coarse mesh will constrain the optimization to a chunkier type of material distribution. It is clearly unreasonable to allow the density of the mesh to control the configuration an optimizer will deliver.

Various remedies were developed early on to reduce this effect. There are three fundamental approaches:

1. perimeter control;
2. density gradient control; and
3. density sensitivity filters.

Perimeter Control

As we can see in Figures 4 and 5, putting a limit on the perimeter to a value of 8.0 would limit the number of holes in our simple configuration to around 16. There are probably many different configurations of arbitrary shaped holes that could meet this target. But the target would clearly enforce a trend away from many small holes. One of the attractions of this method is that it is cheap to calculate and enforce this constraint in the optimization process. The main problem is that it is not physically meaningful as a parameter and is difficult to assign any kind of intuitive value to. A mathematical analogy is normally used that assesses the variation in density from each element to its set of neighbors. Fig. 6 shows a simple schematic of this. Element 1 is being assessed by measuring the density jump, dp = p2-p1, to one of its neighbors, element 2. This density jump is weighted by the element edge length L. The summation of all dp * L is made for element 1. The same process continues throughout the mesh and all values are summed. A constraint is applied to this total value, hence suppressing the tendency for density change across elements. This does have the advantage of being a global constraint, but again it is difficult to come up with a good value, and quite a few experimental runs are needed to assess the influence.

Density gradient control

In this method, a physically meaningful length G, is defined as being a limit on the gradient of the density. The length G spans an arbitrary number of elements. Fig. 7(a) shows the idea schematically. Because the maximum density is 1.0 and the minimum is 0.0, then the steepest gradient is shown acting over length G. This means we are forcing the material distribution to clump together over the distance 2G, as shown—hence, this gives an effective minimum member size. In practice, because the penalty is applied to intermediate densities during iteration steps, the distribution will migrate to that shown in Fig. 7(b).

In practice, more sophisticated variations are used within the optimizers, as it would be expensive to apply the huge number of constraint equations that this implies. However, the basic principle remains.

Density Sensitivity Filters

These methods use the sensitivity of the optimization responses. As the density of an element is changed, then the global compliance will change slightly. This is the sensitivity that is being used. Each element in the mesh in turn becomes a target. A fixed distance r is defined around each target element, as shown in Fig. 8. From the target to the perimeter of the circle with radius r, all surrounding element sensitivities are forced to follow a linear decrease to a value of 0.0 at the perimeter. The effect of this is to eliminate any voids within the

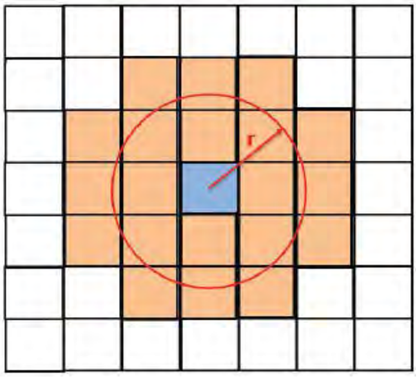


FIG. 8: Density sensitivity filter method.

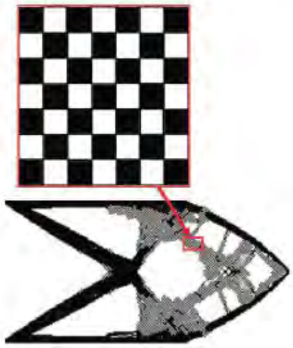


FIG. 9: Typical checkerboarding result.

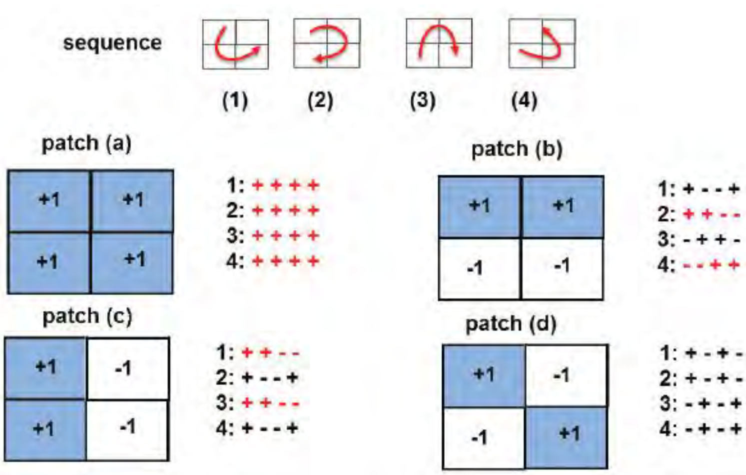


FIG. 10: Connectivity logic assessment in checkerboarding.

area or volume defined by r and to enforce a "gray" type of distribution of decreasing density. However, because the overall optimization task is iterative, the penalty distribution method will rapidly migrate this distribution toward a sharper distinction between material and nonmaterial (density 1.0 and density 0.0, respectively). It will thus suppress fibrous or filigree type configurations with a width less than 2r.

Checkerboarding

There is a tendency for elements to mesh together into a pattern that is similar to a checkerboard, as shown in Fig. 9. Alternating elements are connected only at the corner nodes, leaving voids between. For many types of elements, this is a stable configuration that does not cause any problems with the FEA solution. It is also a physically meaningless solution, but as in the case of the foam-like solutions seen earlier, it is numerically a relatively stiff solution. It is in fact stiffer than any equivalent "sensible" material distribution. So, it will minimize compliance and be very attractive as a solution to the Optimizer.

Various ways have been developed to suppress this effect. The mesh dependency control methods described earlier will tend to minimize the checkerboarding effect. However, relying only on these controls would mean that thin member solutions would always be suppressed, unless the controlling distance was set very close to the element size. More specifically, checkerboarding controls look directly at the connectivity logic in a group or patch of elements. This is shown schematically in Fig. 10.

A patch of four elements can have one of four configurations as shown by patch (a) through patch (d) in Fig. 10. A set of four sequences (1) through (4), moving between these elements is shown in the upper sketch. A pattern describes how the elements flip between non-zero density, (+1) and zero density (-1). The various patterns are shown to the right of the patch configurations. A monotonic sequence (colored red) is defined as one that stays constant, increases or decreases. An oscillating sequence (colored black) flips between positive and negative. All patches except patch (d) show at least one example of a monotonic pattern. So, each patch of elements within the mesh is searched for at least one monotonic sequence. If none are found, then there is a checkerboard patch present; this can be eliminated by smearing effective material over all four elements in the patch.

There are quite a few variations on this technique.

The basic numerical approach behind the SIMP method has been shown, together with provisions for mesh independency and checkerboarding. In part 2 we will look at the alternative objectives and constraints available. We will also see how manufacturing constraints are enforced, and derive some general guidelines for controlling topology optimization. **DE**

....

Tony Abbey *works as training manager for NAFEMS, responsible for developing and implementing training classes, including a wide range of e-learning classes. Check out the range of courses available, including Optimization: nafems.org/e-learning.*

INFO ➜ GrabCAD: GrabCAD.com

References

[1] grabcad.com/challenges/ge-jet-engine-bracket-challenge

[2] sffsymposium.engr.utexas.edu/sites/default/files/2014-110-Carter.pdf

For more information on this topic, visit digitaleng.news

The State of Electronic 3D Printing

BY BRIAN ALBRIGHT

Optomec uses Aerosol Jet technology for electronics 3D printing. ***Image courtesy of Optomec.***

3D ELECTRONICS PRINTING is still an emerging technology, but production systems are now in place in a few industries, and these innovative additive manufacturing solutions appear poised for more growth.

According to "Opportunities for 3D Printing in the Electronics Industry" from SmarTech Publishing, the technology began being mainstreamed in the electronics industry in 2015 after being used for years in research and development. Initial applications include direct manufacturing of antennas, interconnects, printed circuit boards, sensors and other devices. 3D electronics printing reportedly will generate $428 million in revenues by 2022, and potentially reach $2.8 billion by 2025.

"We are seeing a surge in interest in the last 12 months," says Martin Hedges, founder and managing director at Neotech AMT. "A lot of industries are waking up to the potential of 3D printed electronics (PE). Another factor is the convergence of classical 3D printing with 3D PE. This will lead to fully-automated, digitally-driven manufacturing."

"About four years ago we started getting interest from commercial companies who were just starting to look at printed electronics for next-generation challenges they were seeing," says Mike O'Reilly, director of product management for Optomec's Aerosol Jet product line. "They couldn't figure out how to address them using traditional manufacturing techniques. We've seen systems go into place—first as pilots and then full production—in a few different markets."

Multilayer printed circuit boards (PCBs) prototyping is an initial driver of electronic 3D printing. Traditional printed electronics require flat surfaces. What 3D printed electronics can do is allow the creation of electronics on 3D surfaces and in variable shapes and configurations. So far, companies in the field are printing electronics components (like PCBs and antennas), as well as embedding electronics into other objects (3D printed objects and traditionally manufactured items). In this case, the circuitry can be printed on an existing object of almost any shape.

Conformal antennas are a common example. Being able to print these antennas can reduce production time and allow companies to create antenna designs that weren't previously possible.

The market is currently dominated by a group of specialist companies, including Optomec, Voxel8, Nano Dimension (that specializes in PCB development) and others.

Production Printing Systems Emerge

3D printed electronics are already being used for end products in consumer electronics, semiconductor packaging, Internet of Things and other applications. Optomec's Aerosol Jet solution is in mass production at the LITE-ON Mobile Mechanical SBC factory in China, printing conformal electronics on consumer devices—a project deployed in conjunction with Neotech.

"LITE-ON won a large contract and couldn't figure out how to fulfill it," Optomec's O'Reilly says. "That was our first major commercial win in the consumer electronics space. They are printing antennas inside of smartphones."

Optomec has also demonstrated its technology for printing capacitive filling sensors and a circuit on a molded tank, as well as printing heater elements on glass. Its technology also can create single-layer circuit boards that emulate multi-layer circuits by building interconnects at circuit crossover points. Materials also can be switched or blended during printing.

Nano Dimension has targeted its DragonFly 2020 3D printer at rapid prototyping for circuit boards. Voxel8 has provided solutions for PCB and flex circuit manufacturing, as well as 3D phased array and antenna printing. The company's printer system uses a two-nozzle arrangement to print both polylactic acid filament and conductive silver ink to create embedded electronics.

O'Reilly says another emerging market is for advanced packaging, including printing up the side walls of stacked chips to printing wafer-level fan-out technology. "Another way to describe it is being able to mount components onto 3D surfaces and wire those components to get a functional circuit," O'Reilly says. "In the automotive world, for example, if I can print a circuit on a plastic substrate and use that as a connection point for interfacing into various electronic components, I can make them lighter and cheaper—and more functional."

There is increasing interest in the technology in the automotive industry, as well as for IoT applications, and some emerging interest for medical devices. Moving forward, 3D printed electronics could allow designers to have more flexibility in how they stack circuits, integrate circuitry into products and possibly enable on-shoring of more electronics manufacturing once the technology is better able to scale.

"There are a lot of other applications in the prototyping/development stage," Hedges says. "I think realistically it is going to take several years to get parts into production for automotive due to industry requirements. Other markets such as white goods, consumer goods or industrial segments could go faster."

The effect of the IoT on printed electronics is still unclear, although there is some interest, particularly in printing sensors. Optomec, for instance, is printing sensors on turbines for one customer. "They are printing sensors up and down the blades to detect stress or strain. They can do real-time health monitoring and just-in-time servicing of the product," O'Reilly says. "They can constantly interrogate those blades and validate that they are still functioning as specified without having to take the system offline."

Luxexcel specializes in 3D printing optical lenses for eyeglasses, but has also tested out printed electronic circuitry to create smart glasses and other products. With 3D printed electronics in the lens, manufacturers could create embedded polarization filters, embed UV or eye-tracking sensors and create eye movement-based control systems or electrically switched sunglasses. There are also augmented reality applications for such lenses.

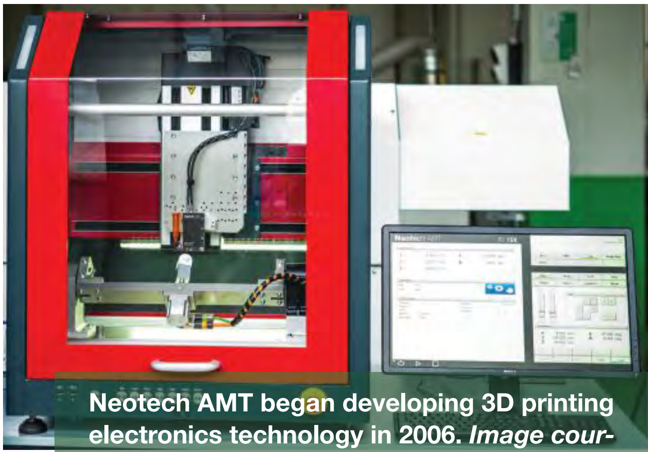
"You can put all kinds of sensors, indicators or LCD screens in the lens," says Guido Groet, chief commercial officer at Luxexcel. "You have to make sure the electronics are not in the field of view, and that they don't create optical aberrations."

Printing the electronics in the lens can make that integration easier, although not every component can be printed. "A lot of sensors have odd materials in them that you can't print, and there are other components that really can't be printed," Groet says.

A pair of projects in Europe are also pushing the envelope. The Eureka PENTA Cluster has a project under way to develop hybrid 3D manufacturing methods that combine printing of polymers with assembly and integration for electronic parts. The MANUNET Project AMPECS will develop processes for printing electronics in and on ceramic substrates.

According to Neotech's Hedges, the value of these processes would be in low- to medium-volume manufacturing of customized/personalized products, or where end users are trying to iterate new products more quickly. Localized manufacturing could also be enabled this way.

"At the moment, it is not clear where the cutoff point will be. I expect it will be different for different product types.



Neotech AMT began developing 3D printing electronics technology in 2006. *Image courtesy of Neotech AMT.*

The slowest part of the process will be their structural build by 3D printing," Hedges says.

Growing the Market for 3D Printed Electronics

Advancements in materials will help expand the use of 3D printed electronics. Optomec, for example, announced improvements in it ability to print and post-process copper and copper/nickel inks for its aerosol jet systems. The company offers print recipes and special hardware to shield the materials during printing and curing. Other vendors are finding ways to provide more functional materials as well, including stretchable materials.

"We've seen advances in noble metals like silver, copper and nickel, as well as some work in palladium and gold," O'Reilly says. "Customers want to get lower-temperature materials like polycarbonate, which has a strong tensile strength but melts at 120°C. There's work being done to develop materials that give you the electrical performance you need, will adhere to the surface of the substrates and pass environmental tests."

There are also conductive filament materials that can embed some level of functionality into the underlying part. However, they may have limited application. "They have lower performance than commercially available inks/pastes," Hedges says. "These materials are already quite mature and are simpler to interconnect to switched multimegabit data service/external systems."

"There's room for everything, and I don't think one approach will win out over another," O'Reilly says. "It depends on the application. Printing plastics and adding conductive filament along the way is just too slow for production right now. But for low-volume applications, that could work." **DE**

Brian Albright *is a freelance journalist based in Columbus, OH. He is the former managing editor of* Frontline Solutions *magazine, and has been writing about technology topics since the mid-1990s. Send e-mail about this article to de-editors@digitaleng.news.*

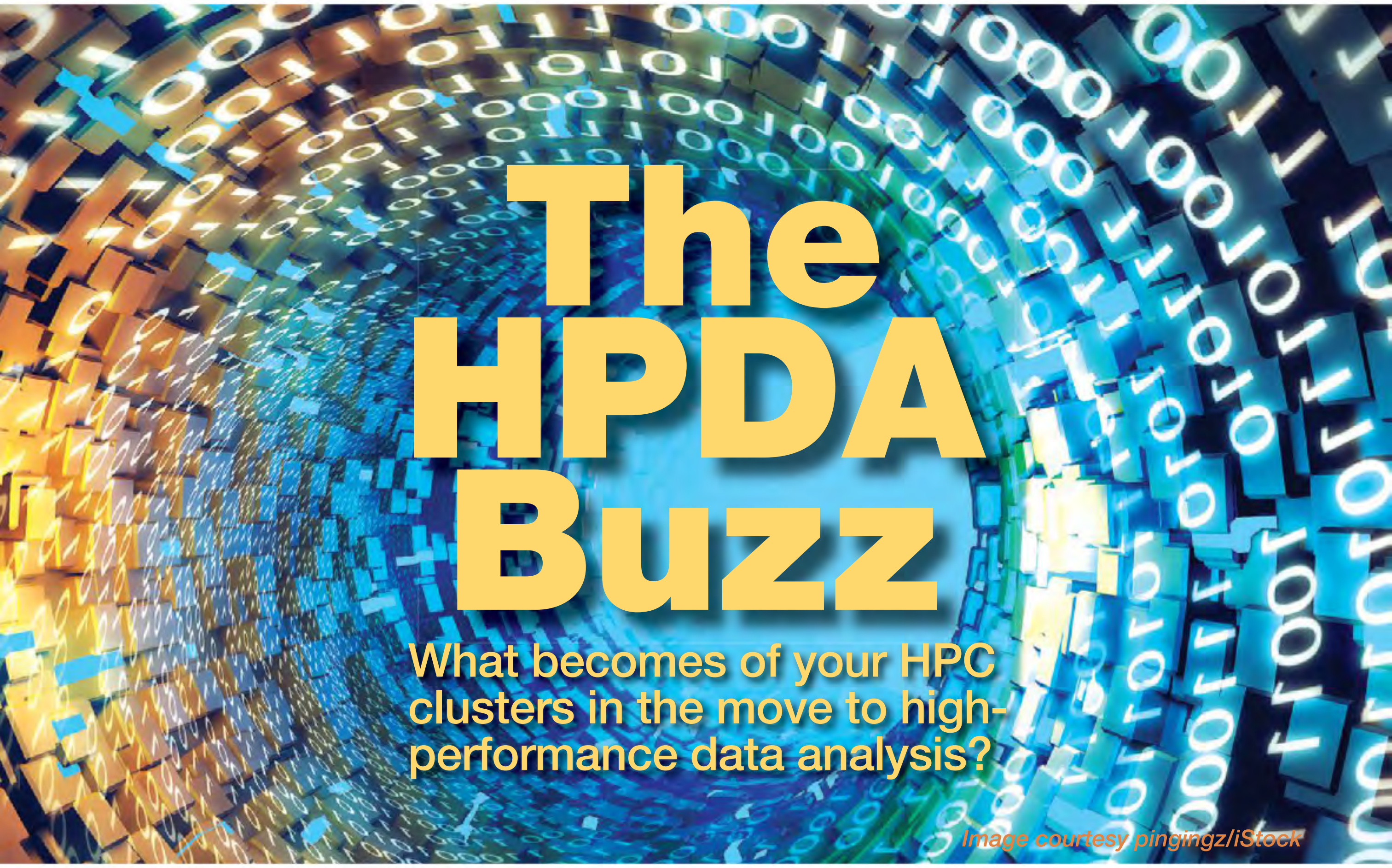
INFO ➜ **Luxexcel:** Luxexcel.com

➜ **Nano Dimension:** Nano-Di.com

➜ **Neotech AMT:** Neotech-AMT.com

➜ **Optomec:** Optomec.com

➜ **Voxel8:** Voxel8.com



The HPDA Buzz

What becomes of your HPC clusters in the move to high-performance data analysis?

Image courtesy pingingz/iStock

BY RANDALL S. NEWTON

From all corners of the design engineering software industry, it is becoming obvious that Big Data is no longer a vague term. In the past 45 days, in different cities with different people, I have been told the following (paraphrased):

- "We are creating an incredible number of FEA (finite element analysis) visualizations. The data is important but we aren't really sure what to do with it." (From an automotive engineering analyst.)
- "The data we generate when we do 3D prints is valuable. But there is no specific way to work with it after we press 'send.'" (From an engineering services executive.)
- "What are we going to do with all of the information this Internet of Things (IoT) will give us?" (From multiple people with various job titles.)
- "We have thousands of parts and assemblies in our inventory, but we don't know how many are duplicates, how many are outdated and how many were never actually used in creating a product." (From an engineer at a Fortune 100 manufacturer.)

All of these views describe the state of engineering today: Terabytes of data are being generated and everyone wants it to become useful information. The solution is called high-performance data analytics (HPDA). There are two aspects to the successful implementation of HPDA: new software that can intelligently mine Big Data and new approaches to hardware that can support the task. This article will examine the hardware side—specifically the use of high-performance computing (HPC) clusters.

High-performance computing evolved as a way to gain scale for challenging computing projects at a much lower price than other options. Engineering adopted HPC for the benefits it brought to increasingly complex simulation and analysis work. With the rise of cloud computing, some engineers are wondering if it is better to leave their existing HPC resources behind and let a vendor like Amazon or Microsoft own the hardware. Researchers at Rutgers University see three emerging HPDA trends regarding data analysis jobs that were once reserved for HPC:

1. **HPC in the cloud**—completely outsourcing large computing problems to cloud-based solutions or private (in-house) cloud technology;

2. HPC plus cloud—the use of cloud resources to complement existing HPC and grid resources, as in responding to unexpected spikes in demand; and

3. HPC as a service—repurposing HPC/grid resources using cloud technology, to gain the flexibility of cloud with the local advantages of HPC systems.

The Rutgers team sees all three as viable options going forward; specific solutions go beyond strictly technical analysis.

Time as a Shrinking Commodity

As sensors proliferate and the IoT becomes commonplace, Big Data will have to also become fast data. It won't do anyone any good to have data in-house proving the new braking system software increases brake pad wear by 5% if it takes weeks to analyze the data. This is an example of real-time streaming analytics—an ideal environment for hybrid HPC/cloud processing.

HPDA provides great value in such situations, allowing engineers to identify and solve problems quickly. In addition, desire for near-or-real-time streaming analytics is driving a new field called activity-based intelligence (ABI), where software routines are guided by data found during HPDA.

HPC clusters can become the hub of these "we need it now" information services. They will divide the problem into two parts: collection and computation. The goal is to manufacture, so to speak, HPC when and where it is needed to solve HPDA problems. Cloud services can use machine learning algorithms to crunch the incoming brake data and spot the trend; the internal, existing HPC cluster can then host the simulations that will be needed to analyze the problem, and off-load simulation to cloud instances of your preferred simulation software when capacity becomes a problem.

Such hybrid use of local and cloud resources sounds well and good, but what if your company is among the vast majority of manufacturers that either have not yet fully deployed an internal HPC cluster or don't have any HPC resources at all? The price/performance curve continues to trend in your favor. There are now pre-tested HPC systems from the leading vendors, designed specifically for smaller manufacturing firms. The Dell HPC System for Manufacturing, for example, is pre-tested with leading applications including Dassault Systèmes SIMULIA and Abaqus, ANSYS Mechanical and Fluent, Siemens Star-CCM+, and LSTC's LS-DYNA. It is a simple system that bundles computing, storage and networking. Installation requires a table, not a raised-floor data center.

Near-term Future of High-Performance Data Analytics

Pacific Northwest Regional Laboratory is a leader in research on HPDA and the adaptability of HPC clusters. It sees the proliferation of open source frameworks, notably Hadoop, as the key to successful management of HPC clusters for HPDA. Because existing HPC systems are often not large enough to handle the new requirements for high-performance analytics, HPDA tools will increasingly be used at all scales, from local HPC clusters to the cloud.

Wanting the benefits of high-performance data analytics doesn't have to be about breaking the bank for new hardware or going exclusively "to the cloud." New software vendors like UberCloud are coming to market with solutions that bridge the gap between existing HPC systems and cloud engineering, with "containers" that make installation and use of the leading simulation products a simple process.

HPDA is not so much a specific technology as it is an approach to putting all of the pieces together. In that regard HPDA is a strategic deployment—not a tactical one. Business and IT analysis firm Transparency Market Research sees the recent development of open source frameworks as having paved the way for affordable deployment of HPDA. "HPDA is seeing remarkable growth due to its highly potential drivers such as its wide adaptability and increasing application areas," the firm notes in a recent report. "The development of open source analytic frameworks has aided organizations to tap the vast amounts of data and manipulate the unstructured data in a way that is understandable to the user by enabling quick application on the data set. HPDA not only provides great value to access the large data sets, but also enables the analyst to work on it with great speed."

HPDA applications can be divided into unstructured, semistructured and structured data types. Deployment options are the three HPC+ options mentioned earlier. For companies ready to invest in high-performance data analysis, the costs will be just about equally split between hardware, software and services. The hardware spend will be to either extend, replace or buy new HPC clusters. The software spend will be for the HPDA tools and for connectors to existing applications; these will come either from existing application vendors or new players in the market. There will also be software spend on additional licenses of key products as their value to your work increases. The services spend will be for additional customization and managed (in-house) services.

All in all, the rise of high-performance data analysis does not require gutting your existing engineering IT infrastructure. It is an upgrade that brings high value to the rapidly accumulating data trove and can be configured to extend the life of your existing HPC resources. DE

Randall S. Newton *is principal analyst at Consilia Vektor, and a contributing analyst for Jon Peddie Research. He has been part of the computer graphics industry, in a variety of roles, since 1985.*

INFO → **Dell:** Dell.com

→ **Pacific Northwest Regional Laboratory:** PNL.gov

→ **Rutgers University:** Rutgers.edu

→ **Transparency Market Research:** TransparencyMarketResearch.com

→ **UberCloud:** TheUberCloud.com

For more information on this topic, visit digitaleng.news

A Patchwork of Technologies

An IoT development platform must impart a broad spectrum of functionality. The true measure of success, however, lies in its ability to deliver these capabilities in a seamless, integral fashion.

BY TOM KEVAN

PERUSE THE MARKET, and you'll find a growing list of vendors touting their "Internet of Things (IoT) platforms." These companies range from public cloud vendors and purveyors of traditional business middleware platforms to networking hardware and enterprise resource planning (ERP) software suppliers. In the end, you're left scratching your head because these companies offer only part of the capabilities needed to develop IoT products.

Customers buying these platforms discover that to get a complete toolkit they have to cobble together components from various vendors. In the end, they're often left with a "Frankenstein" solution that is difficult to manage and slow to enable innovation.

To appreciate the challenge involved in assembling the subsystems required to create an IoT development platform, just consider all the technologies that come into play. Most technology providers and design consultants agree that such a platform should support

- sensors for data collection;
- a microcontroller to support communications, data collection, and actuation;
- wired or wireless connectivity for data transmission (Fig. 1);
- actuators for performing work;

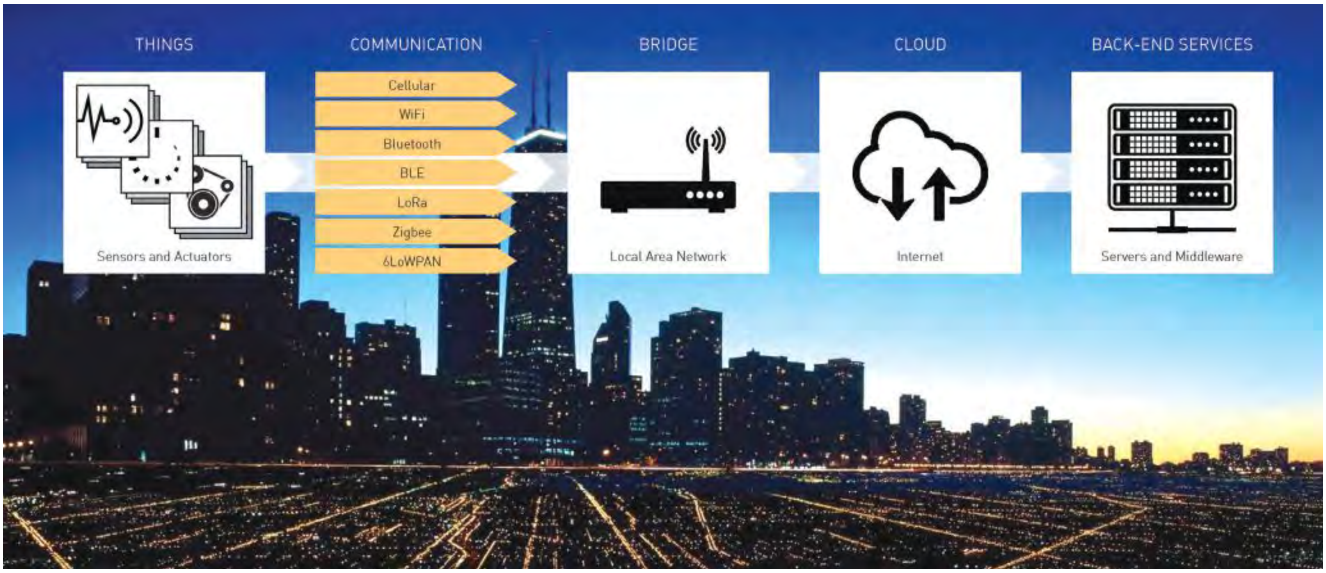


FIG. 1: An IoT development platform should enable design engineers to provide across-the-board connectivity, creating bridges between "things"—that range from sensors and apps to industrial systems—and the cloud and back-end services. To do this, the platform must be flexible enough to work with the full spectrum of interface and communications technologies. *Image courtesy of Optimal Design.*

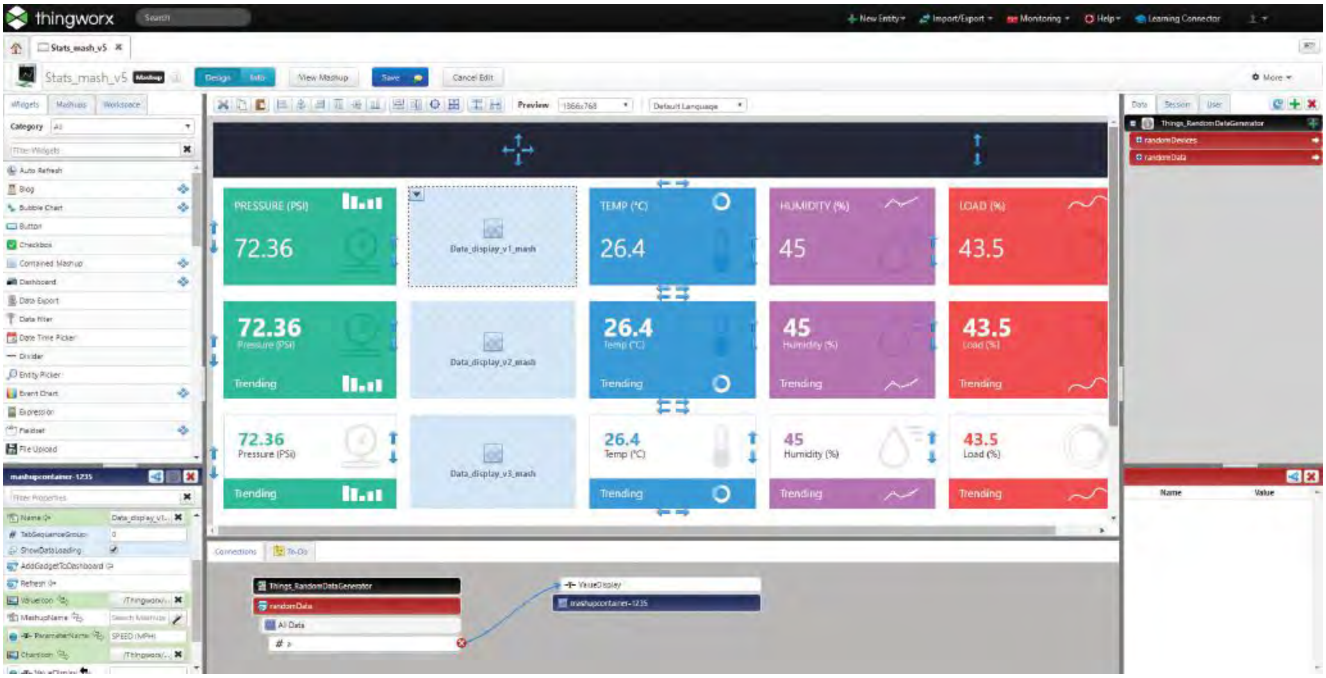


FIG. 2: Effective IoT platforms give developers the ability to aggregate and present data in a way that makes sense within the context of the application. ThingWorx' Mashups allow developers to create apps that collect, visualize and analyze critical data with panels and widget. *Image courtesy of PTC.*

- memory for storage and to support a wireless protocol stack;
- I/O and peripherals for physical access to onboard resources;
- power management for ensuring long periods of usage without human intervention;
- software for analyzing and translating data; and
- application services for adding value.

Given the complexity of the functionality involved, it's clear that the value that IoT development platforms provide is a function of how well they integrate the key capabilities required to innovate new solutions quickly. The more complete the platform, the greater the benefits it can deliver to users.

Unfortunately, finding a platform with a complete toolset is precluded by the fact that the spectrum of functionality required in IoT devices is simply too diverse for one platform to enable. The best a user can hope for is to find a platform that serves the specific application at hand.

"It seems unlikely that a single provider could cover the broad spectrum of connected devices," says Todd Zielinski, senior director of electrical engineering at Bresslergroup. "The extreme disparity in size, power requirements, processing requirements and so on makes a single platform hard to envision. Development platforms can be fairly complete in what they can deliver but are generally focused on a particular application range."

Given these limitations, the sticking point for developers is how best to craft a platform to deliver the required functionality.

Making Enlightened Choices

This battle over the composition of development platforms centers on differences of perspective and emphasis. The market simply cannot agree on whether platforms should be hardware-centric, software-centric or a mixture of both.

"There is a mix of development platforms available in the marketplace," says Joe Kreidler, director of Electrical and Software Engineering at Optimal Designs. "Many IoT development kits are hardware-based, with supporting software development kits (SDKs), such as Intel's Edison IoT development platform. Some development platforms are software only, like Amazon's IoT platform, which provides an SDK that the developer must port and embed into their device."

The reality is that the approach taken in a development platform often depends on the supplier's business model. Hardware vendors, such as Intel, provide SDKs that run only on their hardware to sell more chips. Software vendors, such as Amazon, provide SDKs that can run on or be ported to many different microcontrollers so they can sell their software services.

It's the job of the development team to choose the approach that meets their needs. "To pick a hardware platform for the project, the team has to balance the feature set, power requirements, size, and device and development cost," says Kreidler. "A software-based IoT development platform provides many hardware options, but often takes more effort to port. A hardware-based IoT development platform can be developed quickly, but may lock the development team into a single-source supply situation."

The Emphasis on Software

Some of the largest vendors see software tools as key to enabling IoT development platforms. From their perspectives, the richer the software feature set, the greater the chance of widespread adoption.

"The IoT platforms seeing the strongest rates of adoption are the ones that offer the most complete technology stacks—from broad connectivity options to application enablement and experience tools, like those required to build mobile and augmented reality apps," says Rob Patterson, vice president of strategic marketing at PTC. "If we think about a platform through a data lens, it's critical that the platform enables the developer to easily aggregate data—either through its own offering or through a collaboration

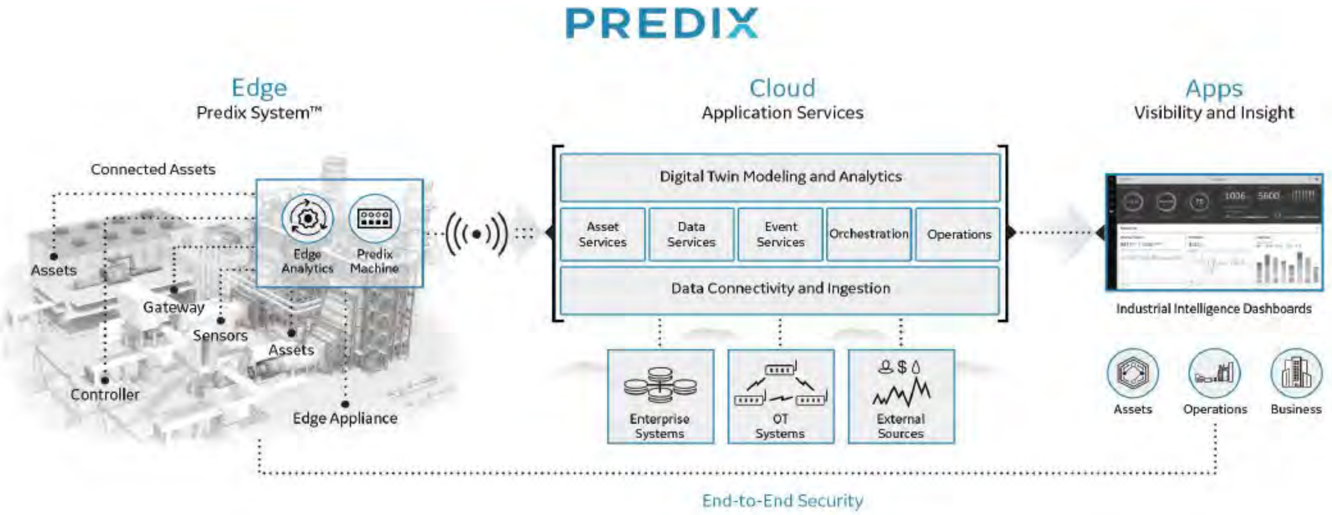


FIG. 3: GE has tailored its Predix IoT development platform for the industrial automation sector, with an eye on providing organizations with the means to create apps that use real-time operational data to facilitate decision-making. *Image courtesy of GE Digital.*

with a cloud provider or another platform. From there, the platform must give developers the ability to model the data in a way that makes sense for their application (Fig. 2)."

Many Hands Make a Complete Platform

Because designers are unlikely to find one development platform to enable all the functionality they require, many in the industry have adopted a partner model in which various platform and service providers work together to deliver the best development tools and cost-effective ways to develop IoT products. Adoption of this approach has grown because few platform providers offer a full technology stack and because existing relationships between platform providers and customers carry a lot of weight.

"In some cases, certain platform providers are missing critical functionality offerings, such as native industrial connectivity, application enablement or augmented reality," says Patterson. "When this is the case, it's not uncommon for these providers to seek out other platform providers and strike up a relationship that grants them access to the capabilities that they are lacking."

Open-Source Options

The market offers a number of "combination" platforms that support comprehensive design projects, but these aren't the only options available to design teams. Engineering groups have created open-source offerings well suited for the preliminary stages of development. These include hardware components, such as low-power boards, single-board processors, field-programmable gate arrays and small boards (shields) that plug into main boards to extend functionality by abstracting functions, such as sensing.

One example of these open-source options is the Arduino platform, which includes a physical board processor, shields with individual libraries of C code and an integrated development environment for writing, compiling and uploading code.

Another well-known platform is Raspberry Pi 2, a tiny computer capable of housing a web server or providing heavy-duty processing, especially when combined with the Python programming language.

"These types of tools play an important role in IoT experimentation, ideation and learning," says John Magee, chief marketing officer for Predix at GE Digital.

The usefulness of these open-source platforms, however, begins to diminish the further the designer gets into the development process. "Open-source development tools are perfect for building proof-of-concept prototypes because of the wide availability of breadboard-friendly hardware and community-supported software libraries," says Matt Heins, Electrical Engineering manager at Optimal Design. "Engineers can get a functional prototype in front of decision-makers faster."

But open source development kits aren't as useful beyond the prototyping phase. For one thing, the cost of development boards alone is generally far beyond the bill of materials cost for many commercial IoT products. To get to the ultimate minimum cost, products need to be custom built and fully optimized. Development boards are built to be easy to use for development work, but they're not a long-term solution because of cost, physical constraints and the inclusion of unnecessary peripheral electronics.

Selecting an IoT Development Platform

Based on the experience of early developers of IoT systems, design teams in search of a development platform should look for offerings that provide a holistic technology stack—one that allows users to connect, create, analyze and implement apps. "What is most important is delivering these capabilities in an integral fashion, with consistent and seamless user interfaces across the capabilities," says Patterson. "Even if multiple technology providers are involved, the overall experience needs to allow the developer to quickly build and deploy useful applications for end users."

Ultimately, the platform should provide design engineers with flexibility. "The challenge in selecting an IoT development platform rests in finding a platform that can effectively scale up or down to match the product's business proposition," says Kreidler.

In terms of hardware, a platform should provide the following development tools:

- gateways for testing wireless connections;
- test SIMS for evaluating cellular connections;
- programming hardware;
- cables for debugging hardware and software;
- battery subsystem development tools to characterize expected life; and
- development boards.

When looking at software development tools, designers should seek a platform with general features that support connectivity, data, analytics and machine learning. "The key software capabilities that GE believes should be included in an IoT platform include a modern application development environment that supports microservice, component-based development in multiple languages; 'digital twin' tools for modeling and managing the software representations of complex 'things;' analytics and machine-learning tools for gaining operational insights from massive amounts of complex data; and edge-computing capabilities for running application logic and analytics on connected edge devices," says Magee.

Although all of these features are important, design teams looking for an IoT development platform should consider all features through the lens of the specific requirements of their application. "IoT development platforms are often difficult to customize in areas like computing power, RAM, ROM, I/O ports and power management," says Kreidler. "The product developer must select a platform that most closely meets the product requirements, configure the system for the product and develop the missing capabilities."

In addition to technical issues, designers should also seek platforms attuned to "housekeeping" considerations, such as cost, part availability and expected product lifetime.

Future Enhancements

Despite the growing presence of IoT platforms, you have to remember that these development environments are still a work in progress. Even now, a suite of new technologies is poised to reshape IoT technology in the coming years. Some of the changes are driven by the surge in connectivity; others, by user expectations; and still others, by decentralization of the computing infrastructure.

Consider the impact that Big Data will have on systems' current ability to extract information. The sheer volume, velocity and variety of IoT data promises to overwhelm current analytics, reducing the payoff that the IoT promises. According to Patterson, traditional methods simply cannot handle the potentially billions of data points with which devices will have to contend. As a result, platform developers will begin to incorporate artificial intelligence and machine learning into their platforms.

Also related to the impact of Big Data, platform developers have begun to seek ways to help users visualize data in the context of a specific application or asset. To this end, they have begun to harness the power of augmented reality.

Next, look at the changes in data collection, storage and analysis brought on by fog, or edge, computing. This distribution of compute resources will require IoT development platforms to have an expanded feature set. In the hardware realm, this change will require support for additional computing resources, such as microcontrollers, hardware accelerators (e.g., field-programmable gate arrays) and larger memory assets. On the software side, IoT development platforms will need more complex firmware development capability to enable IoT devices to work with multiple hosts and interfaces.

One of the areas that will greatly benefit from these new capabilities is the industrial sector. "There's a growing expectation that IoT platforms will support edge connectivity," says Patterson. "Edge capabilities are important, particularly in the industrial setting, where organizations often need to keep data on the premises, either for security reasons or because they cannot risk poor latency through a connection to the cloud or a data center (Fig. 3). Keep in mind that edge computing is evolving quickly, and as more horsepower is available at the edge, more computing tasks will be able to take place there."

Just Getting Started

IoT development platform developers are working in an environment with few rules and fewer best practices. That's because the concept of what these platforms are supposed to be is constantly changing. Compounding the situation, the content and direction of the development environments are shaped nearly as much by vendors' business models as they are by design principles.

Technology providers still have to sort out a number of issues, ranging from the right balance between cloud and edge resources to the establishment of standards that will facilitate interoperability and the role of open-source development tools.

Design engineers find themselves wanting to get in the forefront of the IoT revolution, but they struggle to find just the right development platform. The good news is that a lot of resources are being devoted to creating these toolkits. The bad news: It could be a while before the developers have worked out all of the bugs from the platforms. **DE**

Tom Kevan *is a freelance writer/editor specializing in engineering and communications technology. Contact him via de-editors@digitaleng.news.*

INFO → **Bresslergroup:** Bresslergroup.com

→ **GE Digital:** GE.com/Digital

→ **Optimal Design:** OptimalDesignCo.com

→ **PTC:** PTC.com

For more information on this topic, visit digitaleng.news

With the advent of IoT, embedded systems should gain much momentum in the immediate future. *Images courtesy of MicroEJ.*

Embedded Emergence

New design skills and philosophies are needed.

BY JIM ROMEO

IN INDIA, INCIDENCE OF road accidents causing death and injury has risen 5% in just one year; about 40% of these are caused by human error or fatigue.

Engineers in India have designed Intelliseat; an Internet of Things (IoT) device whereby sensors embedded into a seat can alert a remote monitor of a driver's behavior and even fatigue level.

Such devices set the pace for a new wave of embedded systems that can and will be even more complex as design teams develop and introduce new products in the years ahead. The complexity of embedded systems is on the rise.

Dynamic Environment

Design engineers and design teams can expect virtual prototyping and simulation with regard to embedded technology to be a dynamic environment in the years ahead.

"Engineers are being challenged by shorter design cycles while needing to innovate in both design and processes to stay ahead in today's globalized economy," says Philipp Wallner, industry manager, Europe, Middle East and Africa (EMEA) for MathWorks. "Functionality that could previously be implemented in a system's mechanics or electronics is increasingly being included in embedded systems. This increases flexibility in designing new industrial components and systems, but requires workflows that must support early testing and simulation using virtual prototypes, instead of more expensive physical component, machine, medical device or plant prototypes."

Digital Twins

Wallner says having virtual representations, sometimes referred to as "digital twins," of the components, machines or plants allows engineers to perform system simulations for early verification and use virtual prototypes to more quickly iterate their ideas.

"We're seeing this innovative approach being used in the design of industrial packaging machinery and ventilator [and or] dialysis medical devices," says Wallner.

Régis Latawiec, chief operating officer of MicroEJ, is upbeat about the future of embedded systems. The company provides embedded software solutions, tools and services for connected devices to design, test and prototype embedded applications. He believes the use of embedded systems will be gaining strong momentum in the near term. Such uptrend will be powered by the benefits embedded systems offer—particularly in an increasingly IoT environment.

"I expect they'll be widely used, and very quickly," says Latawiec. "Properly used, they can have a huge impact on a team's development costs, agility and time to market, which, in perhaps not that order, are the three greatest demands on embedded systems design these days, especially with IoT."

He points out that it is possible to reuse simulated prototype designs as you iterate, which facilitates speed and lowers cost.

Design Benefit

"Iteration itself is also easier because switching components just takes a click, not a soldering iron," Latawiec adds. "That's better for software, hardware and even the marketing team, who will want to quickly validate new concepts to fit a fast-evolving marketplace." For a design team, it fosters more collaboration. "It softens the software team's dependence on the hardware team, allowing them to work in parallel instead of forcing the software team to wait on certain hardware milestones," Latawiec adds.

"And something that especially concerns design engineering firms is having a reasonable estimate of performance as early in a project's timeline as possible," says Rajaram Radhakrishnan, who is the senior vice president and Global Markets for the Manufacturing, Logistics, Energy and Utilities sector for Cognizant. He, too, expects a more rapid adoption of embedded systems.

He sees the demand for virtual prototyping and simulation increasing non-linearly. Such growth will be driven by consumer demand, including personalization. This means there's a need for more options in a variety of product categories—causing a surge in demand.

With demand high, expect complex and integrated design requirements to change the game for new product introduction techniques and processes.

"These factors demand a much more agile and first-time-right design philosophy—thus necessitating the increasing demand for virtual prototyping and simulations," says Radhakrishnan. "Additionally, I believe that an extension of simulation's activity going right into the digital manufacturing arena for an integrated and iterative product and manufacturing process simulation will add a new dimension to the design for manufacturability paradigm."

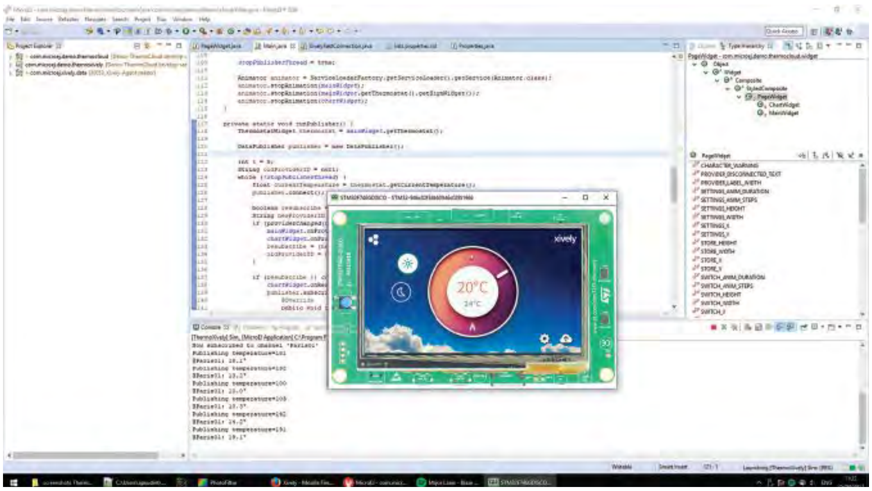
Preparing for the Embedded System Future

What can design engineers do now to capitalize on the expectation that embedded systems technology will become more prevalent in the near term?

"We anticipate embedded systems requirements to grow in high double digits—this is more secular than sectorial," says Cognizant's Radhakrishnan. "While the increased adoption and volumes in autonomous vehicles and unmanned systems will create a higher demand in high value and asset-intensive industries, the revolution in everyday low-value goods that are just $50 and above could see a huge spurt in adoption of embedded systems. Therefore, design engineers should have wide-ranging domain knowledge requirements and understanding, in addition to learning embedded systems design and development."

He also sees an impending demand for technology expertise to accommodate demand, as well as a need to change design mindsets and philosophies.

"One of the key challenges will be to learn 'agile software' development, as traditional linear waterfall development models are fast becoming obsolete," he says. "For example, there is a large number of modules and parts in the automotive industry, so a model-based development approach is a dire need. New product introduction cycles are already in danger of creeping up beyond 24-month benchmarks, as product complexity increases manifold. The use of Big Data analytics as a critical input for simulation is another area that designers will need to quickly familiarize with. Data from connected products and big data analytics can create powerful simulation opportunities—digital twins—of live products that can fundamentally transform the design efficiencies and improve product reliability."



Embedded technology may improve team collaboration, allowing hardware teams and software teams to be more reliant on one another and subsequently more effective and efficient.

MathWorks' Wallner agrees, and sees the use of digital twins to create live products at the outset of new product introductions. "Engineers should start building and using models or digital representations—digital twins, of their components and systems right from the beginning," says Wallner. "This will enable them to perform system simulations to test and verify software on the embedded systems early in the design process. Engineers should also become familiar with production code and documentation generation from Simulink and Stateflow models for vendor-independent implementations that can be used on different embedded platforms including PLCs [power line communication] and industrial PCs. This automatic generation workflow also facilitates complying with necessary regulations and certifications such as IEC 61508 and IEC 62304."

Latawiec says that as embedded systems become more widespread from the overall demand for real-world data collection, hardware will be commoditized the way PCs and smartphones are, and the technology will become more uniform.

"On the software side, though, embedded systems will still require specialists of two kinds of disciplines: electronics and electronics software. For the latter, there are only about half a million such specialists—embedded C programmers, in the world." The talent pool is limited, and he says we can expect to see more high-level development environments to embedded systems.

"Building in Java instead of C, for example, increases the talent pool by 20-fold," says Latawiec. "Engineers should keep this in mind before diving into embedded C to chase demand; keeping strong in object-oriented design, agile practices, etc. will be better in the long run." **DE**

Jim Romeo *(JimRomeo.net) is a freelance writer based in Chesapeake, VA.*

INFO ➜ Cognizant: Cognizant.com

➜ MathWorks: MathWorks.com

➜ MicroEJ: MicroEJ.com

For more information on this topic, visit digitaleng.news

Small and Beautiful

HP rethinks the workstation with its deceptively tiny Z2 Mini G3.

BY DAVID COHN

HP CONSISTENTLY DISTINGUISHES ITSELF as a technology leader. Nowhere was this more apparent than when the new HP Z2 Mini G3 workstation recently arrived in our office for review. First unveiled at Autodesk University, the Z2 Mini is billed as the first mini workstation designed for CAD users. As its name implies, the HP Z2 Mini is tiny, measuring just 8.5x8.5x2.25 in. and weighing a scant 4.85 pounds—more like a thin client than a full-fledged workstation. Yet, the diminutive system is packed with workstation features.

Why create such a small system? Desktop space is at a premium. In addition to being able to sit on a desk in either a horizontal or vertical orientation, the HP Z2 Mini can be mounted under your desk, behind your monitor or on a display arm. HP sells a VESA mounting sleeve with standard VESA mounting holes that, when rotated, can enhance security by blocking access to USB ports.

The system is enclosed in a charcoal gray metal case with its corners beveled at 45° angles. Grills behind the bevel in each corner allow the airflow necessary to cool all of the components packed inside. Because its small size leaves no room for a conventional power supply, the Z2 Mini requires an external power brick, similar to a laptop. Like the system itself, however, the 200-watt power supply included with our evaluation unit was also small, measuring 6.75x3.75x1.0 in. and weighing 2.12 pounds.

When positioned horizontally, the front of the case sports only a power button and the HP logo, whereas the left side includes a pair of USB 3.0 Type A ports and a combination headphone/microphone jack connected to the built-in audio that drives a pair of 2-watt speakers. All other connections are on the rear panel and include an RJ45 network jack, two additional USB 3.0 Type A ports, two USB 3.1 Type C ports, four DisplayPorts, a security lock slot and the external power supply connection. You can connect up to six monitors. When the system is out of reach, it can be powered on using the keyboard or mouse.

The new HP Z2 Mini G3 packs workstation performance into a deceptively tiny case that makes it easy to access the interior. *Images courtesy of HP.*

Packed with Power

As with any workstation, it's what's inside that counts. Again HP makes no compromises. A slide on the rear panel releases the top cover, providing tool-less access to the interior. Inside, a 1TB 7200rpm hard drive—standard in the base configuration—partially conceals the expansion slots, whereas a metal plate and adjacent fan cover the CPU and memory sockets.

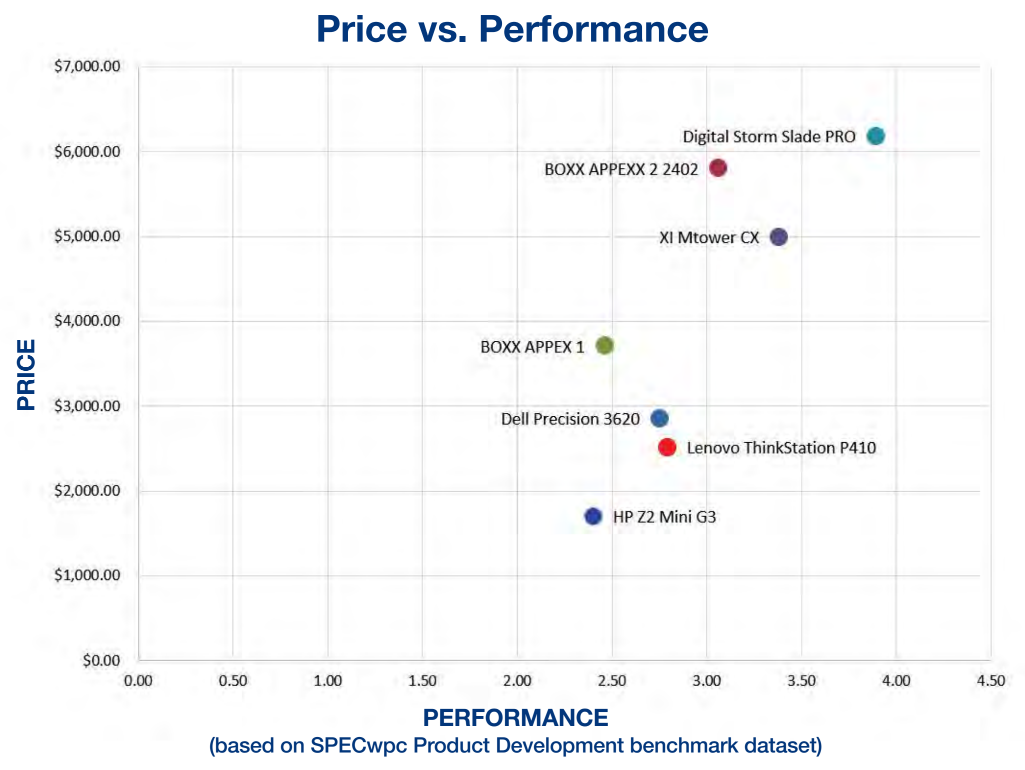
The HP Z2 Mini is based on an Intel C236 chipset and supports Intel Xeon E3-1200v5 and Intel Core processors. With a starting price of $699, the entry-level configuration uses an Intel Core i3-6100 3.7GHz dual core CPU. For our evaluation unit, however, HP included a Core i7-6700 processor, which adds $350 to the base price. This 3.2GHz Skylake CPU has a 4.0GHz maximum turbo speed and includes 8MB Smart Cache and Intel HD Graphics 530. HP also offers a choice of five other CPUs.

The base configuration does not include a discrete CPU, but our evaluation unit came with an NVIDIA Quadro M620 CPU. This Maxwell-based graphics card, with 2GB of GDDR5 memory and 512 CUDA parallel processing cores, features a 128-bit interface and 80GB/sec memory bandwidth. This is the only discrete GPU offered and adds $199 to the system cost.

Single Socket Workstations Compared

	HP Z2 Mini G3 one 3.2GHz Intel Core i7-6700 quad-core CPU, NVIDIA Quadro M620, 32GB RAM, 250GB SSD and 1TB SATA HD	Lenovo ThinkStation P410 one 3.6GHz Intel Xeon E5-1650 v4 6-core CPU, NVIDIA Quadro M4000, 16GB RAM, 1TB SATA SSD HD	Dell Precision 3620 one 4.0GHz Intel Core i7-6700K 4-core CPU, NVIDIA Quadro M4000, 32GB RAM, 512GB PCIe SSD and two 1TB SATA drives in RAID 0 array	BOXX APEXX 2 2402 one 4.0GHz Intel Core i7-6700K 4-core CPU over-clocked to 4.4GHz, NVIDIA Quadro M5000, 16GB RAM, 800GB PCIe SSD	BOXX APEXX 1 one 4.0GHz Intel Core i7-6700K 4-core CPU over-clocked to 4.4GHz, NVIDIA Quadro K1200, 16GB RAM, 512GB PCIe SSD	Xi Mtower CX one 3.0GHz Intel Xeon E5-1660 v3 8-core CPU over-clocked to 4.1GHz, NVIDIA Quadro M5000, 16GB RAM, 256GB PCIe SSD and 1TB SATA HD
Price as tested	$1,698	$2,515	$2,860	$5,806	$3,711	$4,997
Date tested	1/20/17	10/26/16	8/5/16	1/30/16	1/30/16	1/25/16
Operating System	Windows 10	Windows 10	Windows 10	Windows 10	Windows 10	Windows 10
SPECviewperf 12 (higher is better)						
catia-04	34.16	89.66	86.07	133.05	34.95	126.16
creo-01	36.80	76.93	72.47	108.03	33.45	107.44
energy-01	0.64	6.34	6.33	11.44	2.56	11.65
maya-04	30.36	63.31	69.94	101.53	31.22	97.68
medical-01	10.99	26.62	26.54	45.12	11.41	45.78
showcase-01	18.69	46.58	45.77	60.37	18.99	61.65
snx-02	28.29	125.39	72.93	121.01	28.47	219.48
sw-03	58.18	106.37	108.73	158.22	70.56	149.88
SPECapc SOLIDWORKS 2015 (higher is better)						
Graphics Composite	2.51	8.08	8.23	7.65	5.17	5.89
Shaded Graphics Sub-Composite	2.04	4.87	4.95	4.19	2.86	3.16
Shaded w/Edges Graphics Sub-Composite	2.58	5.97	6.36	5.57	3.92	4.22
Shaded using RealView Sub-Composite	1.94	6.43	6.35	5.45	3.56	4.32
Shaded w/Edges using RealView Sub-Composite	3.33	9.99	10.19	9.01	6.17	7.20
Shaded using RealView and Shadows Sub-Composite	1.73	7.23	7.07	6.77	4.15	4.97
Shaded with Edges using RealView and Shadows Graphics Sub-Composite	2.84	10.47	10.57	10.29	7.20	7.67
Shaded using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	2.21	16.01	15.04	14.87	7.78	11.94
Shaded with Edges using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	3.37	22.75	21.89	21.17	11.63	17.69
Wireframe Graphics Sub-Composite	3.46	3.26	3.88	4.19	4.17	2.98
CPU Composite	2.78	5.08	4.96	6.09	6.75	5.87
SPECwpc v2.0 (higher is better)						
Media and Entertainment	2.53	2.84	3.22	3.52	2.84	3.84
Product Development	2.40	2.79	2.75	3.06	2.46	3.38
Life Sciences	2.59	3.03	3.25	3.65	2.96	4.19
Financial Services	3.11	4.60	1.40	1.54	1.53	2.59
Energy	1.97	3.11	2.77	3.17	2.70	4.37
General Operations	1.47	1.14	1.58	1.99	1.93	1.78
Time						
Autodesk Render Test (in seconds, lower is better)	62.40	50.10	58.20	41.70	46.30	25.30

Numbers in blue indicate best recorded results. Numbers in red indicate worst recorded results.



The HP Z2 Mini has two SO-DIMM (small outline dual in-line memory module) sockets, and HP includes 8GB of RAM in the base configuration. Our evaluation unit was equipped with 32GB, installed as a pair of 16GB 2133MHz modules. Newer systems now include 2400MHz memory.

In addition to the standard SATA drive, the HP Z2 Mini supports an M.2 PCIe drive. Our evaluation unit included a 256GB HP Z Turbo Drive and the OS was preloaded onto this solid-state drive. An integrated gigabit LAN is also standard, but our evaluation unit included an Intel dual band wireless AC 82655 module providing 802.11ac wireless plus Bluetooth 4.2.

Decent Performance

Although the HP Z2 Mini performed well in all of our benchmarks, with its modest GPU, its results were more comparable with mobile workstations than desktop systems. On the SPECviewperf tests, the Z2 Mini lagged behind all of the other desktop systems we have tested recently, including the diminutive BOXX APEXX 1 we reviewed last year. This also proved to be true on the SPEC SolidWorks 2015 benchmark.

We also ran the demanding SPECwpc workstation performance benchmark. Here, the performance of the Z2 Mini was a mixed bag. Results based primarily on CPU and I/O were good, though it lagged behind on those tests focused primarily on GPU performance. The system remained cool and relatively quiet throughout our tests. HP claims that the Z2 Mini is 63% quieter than an HP business-class PC, but the sound level during our tests averaged 42dB while running more intensive benchmarks and climbed as high as 50dB.

Although HP rounds out the base configuration with a USB keyboard and mouse, our review unit came with a 104-key HP wireless keyboard and mouse. A USB stick provides wireless access for the keyboard and mouse. The system came preloaded with Windows 10 Professional 64-bit. Windows 7 Professional is also available through downgrade rights from Windows 10 Pro, or you can save $177 and purchase a Linux-ready system without a preloaded OS.

Like other HP professional Z-series workstations, the Z2 Mini G3 is certified for more than 20 critical applications including AutoCAD and SOLIDWORKS, and is backed by a three-year warranty that covers parts, labor and on-site service.

The new HP Z2 Mini G3 offers flexibility and workstation performance in an inventive design. It is a beautiful example of form and function, with a price guaranteed to place it discretely on (or under) the desks of many *DE* readers. **DE**

David Cohn *is the technical publishing manager at 4D Technologies. He also does consulting and technical writing from his home in Bellingham, WA and has been benchmarking PCs since 1984. He's a contributing editor to* DE *and the author of more than a dozen books. You can contact him at david@dscohn.com or visit his website at dscohn.com.*

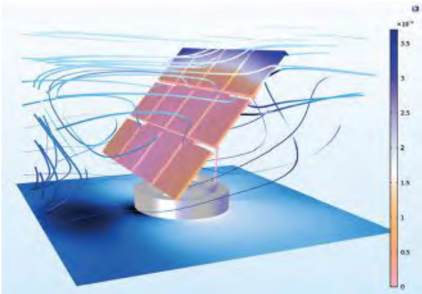
INFO ➜ HP: hp.com

HP Z2 Mini G3

- **Price:** $1,698 as tested ($699 base price)
- **Size:** 8.5x8.5x2.25 in. (WxHxD) notebook
- **Weight:** 4.85 pounds (plus 2.12-pound external power supply)
- **CPU:** Intel Core i7-6700 3.2GHz quad-core w/ 8MB cache
- **Memory:** 32GB DDR3 2133MHz
- **Graphics:** NVIDIA Quadro M620 w/2GB GDDR5 and Intel HD Graphics P530
- **Hard Disk:** 250GB PCIe M.2 SSD and 1TB 7200rpm SATA
- **Floppy/Optical/Video/Modem:** none
- **Audio:** integrated with 2-watt speakers
- **Network:** integrated Intel i219-LM gigabit network; integrated dual-band wireless 802.11a/b/g/n/ac Wi-Fi; Bluetooth 4.0
- **Other:** four USB 3.0, two USB Type C 3.1 ports, (one with charging), HDMI 4.1, microphone-in/headphone-out combo, A/C power, RJ-45, two Thunderbolt 3.1, smart card reader

Each week, ***Tony Lockwood*** *combs through dozens of new products to bring you the ones he thinks will help you do your job better, smarter and faster. Here are Lockwood's most recent musings about the products that have really grabbed his attention.*

EDITOR'S PICKS



COMSOL 5.3 Released

Multiphysics system and simulation app platform deploys new solvers and more.

COMSOL Inc. announced the 5.3 versions of its COMSOL Multiphysics modeling, simulation and simulation app-development system, as well as its COMSOL Server platform for distributing, managing and running simulation apps.

Version 5.3 debuts boundary element method (BEM) functionality, a new algebraic multigrid (AMG) solver for CFD (computational fluid dynamics) analyses and enhanced app design and deployment capabilities.

MORE ➔ digitaleng.news/de/?p=36690

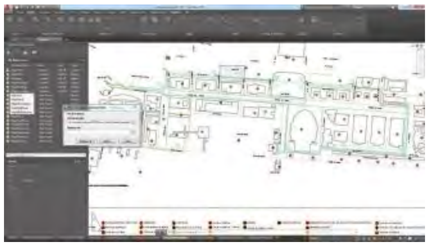
AutoCAD and AutoCAD 2018 LT Released

New tools for missing references, enhanced PDF imports among release highlights.

A quick description of what's new in the 2018 versions of AutoCAD and AutoCAD LT is that there are new tools and performance enhancements engineered to help you design faster and with fewer potential hassles.

Among version 2018's notable new capabilities are a set of integrated tools to make fixing broken paths for externally referenced files easier. Autodesk says that these will save time and minimize frustration. Plus, AutoCAD 2018 introduces updates to the DWG format that can improve the efficiency of open and save operations.

MORE ➔ digitaleng.news/de/?p=36484



Notebook Workstation for 3D Modeling

Xi PowerGo 15/7 extended with Intel Core i7 processors, Quadro P3000 graphics.

@Xi Computer Corp. has released a model in its Xi PowerGo 15/7 notebook workstation series that has the latest NVIDIA Pascal architecture-based Quadro P3000 GPU and a seventh-generation Intel Core i7 mobile processor. The newly extended Xi PowerGo 15/7 is now available for immediate customization and delivery.

Xi PowerGo 15/7 models run Intel Core i7 processors, NVIDIA GeForce or Quadro graphics.

MORE ➔ digitaleng.news/de/?p=36372

Stackup Analysis Software Launched

Analyzer bridges the gap between manual tolerance stackups and advanced tool.

Sigmetrix has released EZtol one-dimensional analysis solution. What EZtol does is analyze your 3D design model using the actual nominal distances between surfaces/features in it. By the way, it works with files from nearly any major CAD system. It helps ensure that your analysis includes all components in the loop. It calculates the worst-case, RSS and statistical results automatically. EZtol creates at-a-glance graphical views of the decision-making details you need.

MORE ➔ digitaleng.news/de/?p=36139

Next-Gen Engineers

Student Design Competition Profile: EcoCAR 3

Reaching for the Pinnacle of Advanced Vehicle Tech

BY JIM ROMEO

To foster the innovation used for automotive design and technology, the Argonne National Laboratory in Illinois hosts a design competition, principally with North American universities, to connect great minds.

Kristen Wahl is the director of the Advanced Vehicle Technology Competition (AVTC) program at Argonne National Laboratory. We spoke to Wahl to understand its EcoCAR 3 program. Here's our conversation.

Digital Engineering: Can you provide an overview of the "EcoCAR 3" program, how it came to be and the intent of the program?

Kristen Wahl: EcoCAR 3 is the most recent advanced vehicle technology competition (AVTC) series sponsored by DOE (U.S. Department of Energy) and GM. Argonne National Laboratory has managed the AVTC program for DOE, in collaboration with the domestic automotive industry since the program began in 1988, seeding more than 20,000 graduates into the automotive and related industries.

EcoCAR 3 challenges 16 North American universities to reduce the environmental impact of vehicles by minimizing fuel consumption and reducing emissions, while improving the vehicle's overall consumer appeal. Teams will follow a real-world vehicle development process (VDP) to design and integrate their advanced technology solutions into a 2016 Camaro donated by General Motors, gaining hands-on experience with industry-leading engineering tools and the latest vehicle components and technologies.

The number of students on each team varies. Typically teams have about 15 to 20 core students, but average 72 students working on the project at their university. Each team will send approximately 13 students and faculty members to the final competition in Milford, MI, and Washington, DC in May.

Argonne National Laboratory highly encourages scientific research–both within the universities and in collaboration with government and industry.

DE: Can you provide some examples of what the event has produced or what you expect it to produce?

Wahl: Teams each have unique innovation concepts, so the results of this research are as varied as the projects themselves. However, with the current direction of the automotive industry, many teams are working on approaches to improve vehicle fuel efficiency through connected or "smart" vehicle concepts, where the car can make intelligent decisions to improve efficiency based on real-time information.

For example, the University of Alabama has begun research into developing a two-mode homogeneous charge compression ignition (HCCI) strategy that is designed to be validated in their competition vehicle. HCCI marries the favorable characteristics of compression and spark ignition engines to achieve thermal efficiencies usually only seen in diesel vehicles. This dual mode is theorized to have the potential to meet modern emissions standards with little exhaust after-treatment.

Wayne State University has selected to investigate the feasibility of using the directed energy deposition (DED) process to fabricate structural and torque-transmitting components for use within their competition vehicle. The intended result will be successful application of a multi-material additive manufacturing process to provide spatial control over placement of multiple materials within the work part during the build sequence.

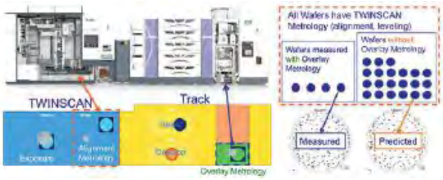
DE: Anything else you can tell us about the event?

Wahl: Our competitions have historically challenged teams to work with new and emerging vehicle technologies. In EcoCAR 3, we're continuing that tradition through our Advanced Driver Assistance Systems activities, where teams are developing computer vision sensors to see and comprehend the roadway situation around them. Teams are using vision sensors to identify vehicles, pedestrians, signs and other elements of the road. More importantly, they will use that information to increase the driver's situational awareness and improve vehicle efficiency. **DE**

Jim Romeo *is a freelance writer based in Chesapeake, VA. Send e-mail about this article to de-editors@digitaleng.news.*

FASTAPPS
Engineering Case Studies

ASML Develops Predictive Metrology Technology for Semiconductor Manufacturing with Machine Learning



In nanofabrication, photolithography is the fundamental patterning step that controls the size of a microchip. During photolithography, a low-wavelength power source is conditioned with optics through an image that is then reduced in size with more optics into a thin film of light-sensitive chemical covering a substrate, typically silicon. This step is repeated until all available surface area on the substrate has been exposed with the same image; the result is referred to as a layer. Multiple exposed layers are needed to create the complex microscopic structures that make up a chip. To prevent yield issues due to connection failures between layers, all patterns between layers must line up as intended.

To ensure layer alignment without affecting throughput, ASML's TWINSCAN photolithography system must limit the number of alignment marks it measures before the exposure step. The general rule is that the time required to measure alignment marks cannot be longer than the time required to expose the previous wafer in the sequence. Due to the large quantity of overlay marks required for a proper overlay model correction, it is not feasible to measure every wafer coming out of a TWINSCAN system.

ASML used MATLAB and Statistics and Machine Learning Toolbox to develop predictive overlay metrology software. This software applies machine learning techniques to come up with a predicted estimate of overlay metrology for every wafer, using alignment metrology data.

"The work we've done with MATLAB and machine learning demonstrates industry leadership in the best use of existing metrology," says Emil Schmitt-Weaver, applications development engineer at ASML. "The papers we've published on this work have attracted the interest of customers looking to improve their manufacturing processes with ASML products."

Challenge

Despite the risk that missed overlay errors could reduce yield, most manufacturers measure overlay for only 24% of the wafer population. With alignment metrology for every wafer collected with the TWINSCAN system, ASML sought to apply machine learning techniques to estimate overlay metrology for wafers and compare it with existing YieldStar metrology.

MORE ➜ digitaleng.news/de/?p=36336

Hyundai Wearable Robotics for Walking Assistance Offer Spectrum of Mobility

BY DONGJIN HYUN, *PH.D., HYUNDAI MOTOR COMPANY*

The Central Advanced Research and Engineering Institute at Hyundai Motor Company develops future mobility technologies. Rather than provide conventional vehicle products to customers, this research center creates new mobility devices with a wide range of speeds for a variety of people, including the elderly and the disabled. As our society ages, there is a greater need for systems that can aid mobility. The Institute is developing wearable exoskeleton robots with NI embedded controllers for the elderly and patients with spinal cord injuries to use.

Researchers wanted to develop a system that could handle complex control algorithms to capture data remotely from various sensors simultaneously and perform real-time control of multiple actuators for a wearable robotics device for walking assistance. The solution involved using the LabVIEW RIO platform, including a CompactRIO embedded system and a real-time controller with an FPGA control architecture provided by Single-Board RIO to acquire data from sensors and control peripheral units, high-speed communication devices, and actuators; and using LabVIEW software to acquire reliable data by conducting real-time analysis and applying various robot control algorithms.

MORE ➜ digitaleng.news/de/?p=36382

➜ For the full application stories, visit digitaleng.news/de/fastapps

AD INDEX

| COMMENTARY |

by Dominic Gallello

Simulation Paves a New Autonomous Testing Era

RIGHT NOW, WE SIMULATE the car and leave the driving to the human. The transition to do both by a machine is a significant shift of the paradigm. The simulation has to be extended and has to predict the behavior of the vehicle, as well as react to changes in the environment. To predict certainty in vehicle performance, automotive companies will have to extend simulation technologies and embrace new ones. The key to achieving this will be to rely heavily on simulation software tools with real-time capabilities and machine learning.

Off-Line to Real Time

Although off-line solutions will continue to solve sophisticated and complex models, the need for real-time simulation is ever increasing, especially in the autonomous vehicle world, for two main reasons.

1. The requirement to connect virtual models to physical hardware (such as sensors, controllers, driving simulators and so on), so-called hardware-in-the-loop (HiL). These physical assets have a defined communication speed. The associated simulation model must be able to keep up with this communication speed. This defines a real-time model.

2. Traditionally, vehicle development (including vehicle dynamics) has been targeted at validating the machine. The human driver, whether following orders (test instructions) or making numerous on-the-fly decisions, was not considered a system that required validation. The concept of autonomous vehicle changes all of that. Now, the "driver," the most complex system on the vehicle, has to be validated as well. This leads to many orders of magnitude for more simulation runs so the ability to solve quickly becomes a valuable asset.

With accurate representation of the vehicle response, we can introduce the model to a computer simulation of a real-world driving environment—complete with other cars, trees, people, buildings and so on. In order to "read" this environment, the autonomous vehicle model is equipped with a variety of sensors that continually monitor its surroundings. At this stage, some physical sensors may be included (HiL) as the necessary physics has not been captured in a virtual model. Based on feedback, the vehicle calculates what to do next and then sends appropriate signals to actuators that drive the car. This behavior is then coded onto the vehicle chassis controller. Until now, the vehicle dynamics model has been effectively a "black box" representation of vehicle behavior. That is, sensor and controls developers have not been interested in *why* a vehicle behaves as it does, only in *how* it behaves. The next generation of vehicle controllers will have an on-board, real-time vehicle model that adapts and learns to account for driver preferences and changing conditions.

Machine Learning

A significant challenge facing autonomous driving is an accurate perception, such as obstacle avoidance and terrain assessment. A self-driving vehicle has to assess the drivable surface, while, at the same time, avoiding a whole range of obstacles.

There are three ways a vehicle can address this:

1. **Self- Supervised Machine Learning**—The terrain encompasses a supervised learning process by generating labels against events like rough road conditions when driving.

2 **Unsupervised Machine Learning**—The terrain is structured into self-organizing maps. This is particularly helpful in measuring distances and normalization.

3. **Deep Learning**—This technique is moving into the autonomous vehicle driving space. It encompasses complex mapping functions and machine learning algorithms to leverage huge amounts of training data from various sensors, and specifically from camera systems.

Various sensors added to the vehicle collect data, apply multi-sensor fusion techniques to consolidate, and reduce the data. AI systems that are learning continuously from experience discerning and recognizing surroundings allow the vehicle to react to environmental changes. Systems on a chip use compute intensive machine learning algorithms for scene interpretation or traffic sign recognition, or issue lane-departure control and notification.

The global automotive industry is committed to the development of the driverless car, but there is a long way to go to standardize communication formats, agree on liability and provide the infrastructure to handle the massive amount of data transfer that will be required. Computer simulation may be the only way to test all of the potential combinations of conditions, and the structured process described here is aimed at supporting the goal of safe, reliable autonomy. DE

Dominic Gallello *is president and CEO of MSC Software (MSCSoftware.com), a fully owned subsidiary of Hexagon AB. Contact him via de-editors@digitaleng.news.*

LS-DYNA®
Smooth Particle Hydrodynamics (SPH)

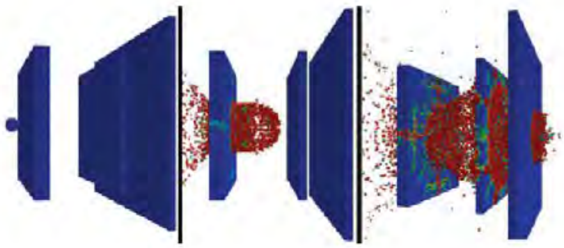
Smooth particle hydrodynamics is a meshfree, Lagrangian particle method for modeling fluid flows and solid bodies. The method was developed to avoid the limitations of mesh tangling encountered in extreme deformation problems with the finite element method and to model the complex free surface and material interface behaviors, including the break-up of solids into fragments. A main difference between classical methods and SPH is the absence of a grid. Therefore, the particles are the computational framework on which the governing equations are resolved. SPH has been applied extensively to problems involving incompressible flows, heat conduction, high explosives, and high velocity impacts. The SPH method in LS-DYNA® is coupled with the finite and discrete element methods to extend its application to a variety of complex problems involving multi-physics.

Applications:

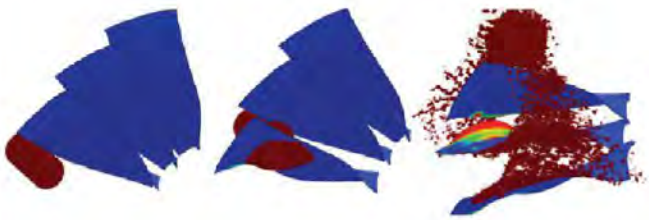
- Forging and Extrusion, Metal cutting, Foam packaging.
- High Velocity Impact, Bird strike.
- Fluid-Structure Interaction.
- Sloshing and Splashing.
- Explosions, Underwater explosions, Soil penetration.
- Incompressible fluids.
- Fragmentation and Spallation of solids.

Features:

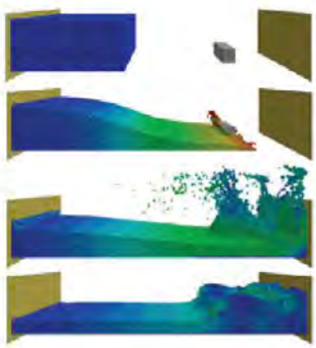
- A Lagrangian framework, that can handle very high deformations with moving boundary, moving interface and free surface, applied for both solid and fluid parts.
- Easy FSI modeling through regular contact options.
- 3D, 2D and 2D axisymmetric versions for both shared and distributed memory computations.
- SPH thermal solver coupling with structure, pure thermal coupling with solid elements.
- Multiple coupling options (interaction methods) between different SPH parts and between SPH particles and solid elements or other particle methods (such as DEM).
- Support for most of the material models used by the solid elements.
- Adaptively convert solid elements into SPH particles to handle severe deformations.



High Velocity Impact problem (Multiple Impacts).



Bird Strike simulation (*Courtesy of DynaS+*).



Fluid-structure interaction simulation.

Youtube Channel:
https://www.youtube.com/user/LSTCandDYNAmore

Twitter:
https://twitter.com/LSTCandDYNAmore

Information - 30-day LS-DYNA demo license: sales@lstc.com

LSTC Livermore Software Technology Corp.
www.lstc.com

DYNA MORE
www.dynamore.de