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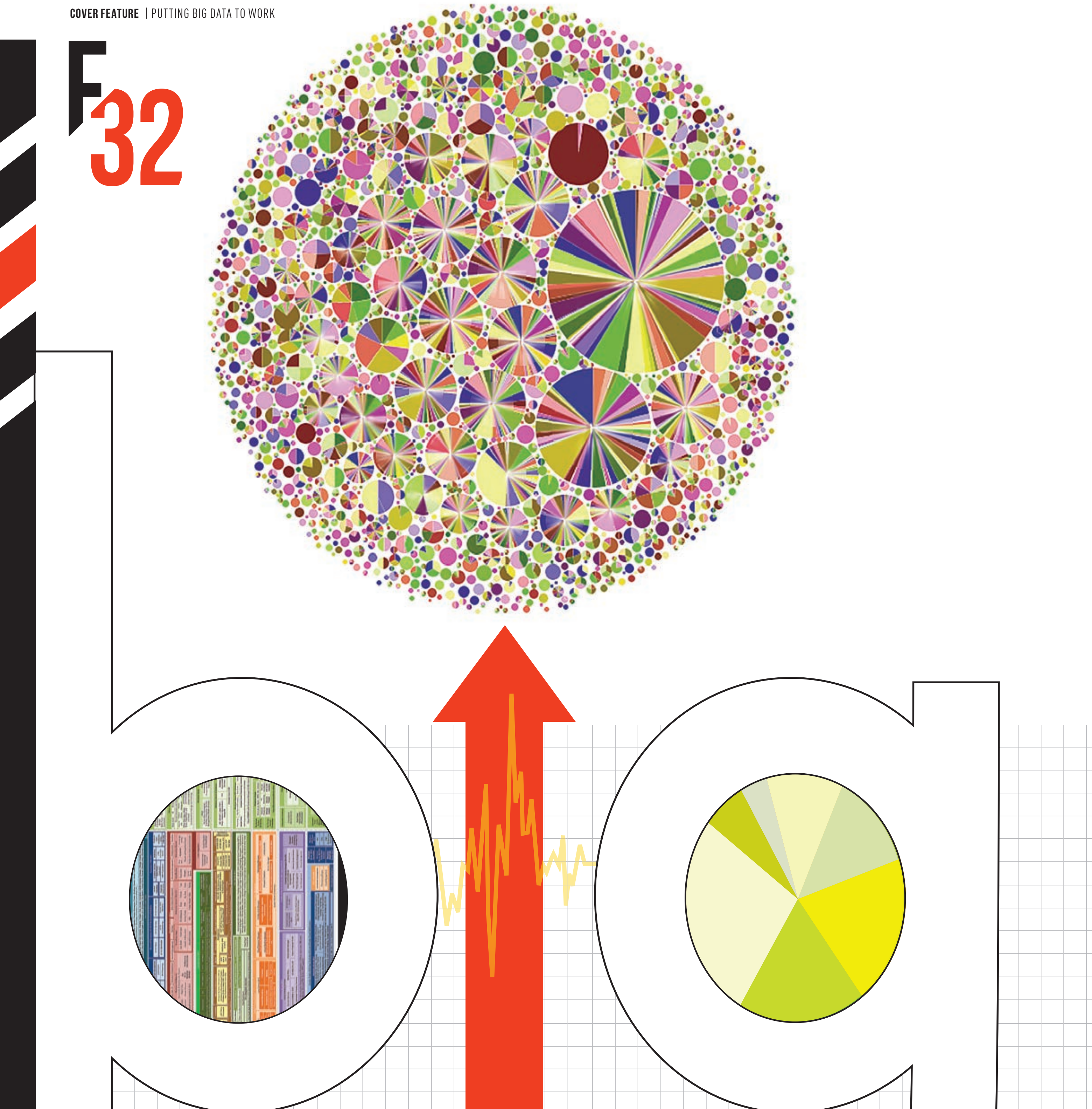


PUTTING BIG DATA TO WORK

BY AHMED NOOR

IMAGINE
WHAT FACTORIES WILL DO WHEN THEY CAN TAKE FULL ADVANTAGE OF **ALL THE INFORMATION AT HAND**

Technologies ranging from supervisory control and data acquisition to enterprise resource planning have made factories smart, and they are getting smarter every day.

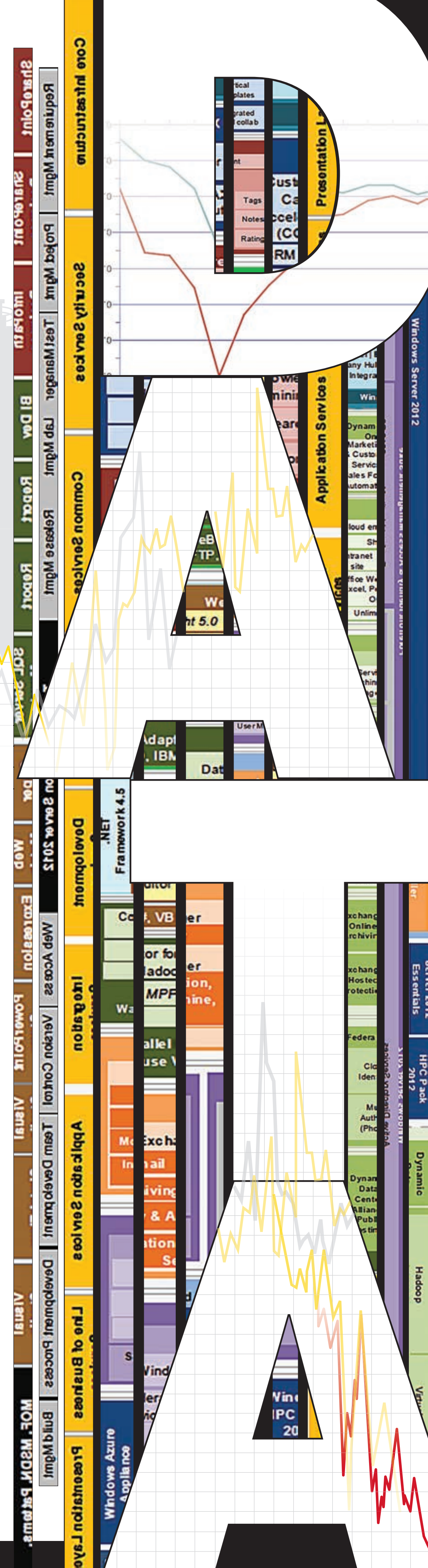
At a missile plant in Huntsville, Ala., for instance, Raytheon Corp. monitors its assembly operations down to the turn of a screw. If a screw is supposed to turn 13 times after it is inserted in a missile component, but it turns only 12 times, an error message flashes, and production is halted until the anomaly is understood and rectified.

Just how much smarter factories can become will be determined largely by the research and development of systems to manage information. Smart factories, after all, are part of the phenomenon popularly known as Big Data.

The challenge of Big Data is that it requires management tools to make sense of large sets of heterogeneous information. In the case of a factory, sources of data include CAD models, sensors, instruments, internet transactions, simulations—potentially, records of all the digital sources of information in the enterprise. The data bank is large, complex, and often fast-moving, and so it becomes difficult to process using traditional database analysis and management tools.

Raytheon's monitoring technology is often called "manufacturing execution software," and several manufacturers are currently using MES to collect and analyze factory-floor data. The systems enable the real-time control of multiple elements of the production process.

Industry stands to reap many benefits from Big Data as more sophisticated and automated data analytics technologies are developed. These technologies



TURN OF THE SCREW

If a screw in this missile fails to complete its full count of turns, Raytheon will know about it immediately and be able to take corrective steps.

Manufacturers already can monitor their operations in real time and in close detail with manufacturing execution software.

BIG DATA AT WORK >>

will help extract value and hidden knowledge from large, diverse data streams.

For example, the vehicle sensors in the Ford Focus electric car produce vast amounts of data while the car is driven, and even when it is parked. While the vehicle is in motion, the driver is constantly updated with information about acceleration, braking, state of battery charge, distance to charge points, and location. And while the vehicle is at rest, the sensors continue to stream data about the tire pressure and battery system.

The driver gets useful, up-to-the-second data, while Ford engineers in Detroit use the car's communication modules and remote application management software to aggregate the information about driving behaviors in order to gain customer insights and plan product improvements. In addition, third-party vendors, like General Electric, AeroVironment, and ECOtality, analyze millions of miles' worth of driving data to decide where to locate new charging stations, and how to protect the fragile utility grids from overloading.

Smart manufacturing has the potential of fundamentally changing how products are invented, manufactured, shipped, and sold.

A typical factory uses information technology, sensors, motors and actuators, computerized controls, production management software, and the like to manage each specific stage or operation of a manufacturing process. However, each plant is an island of efficiency.

Smart manufacturing aims at integrating these islands, enabling data sharing throughout the plant and among plants in a company.

A new wave of inexpensive electronic sensors, microprocessors, and other components enables more automation in factories, and huge amounts of data to be collected along the way. Managers can get instant alerts about potential problems or study the data to find ways to boost efficiency and improve performance. In addition, enhanced knowledge of the workplace promises to improve worker safety and to protect the environment because it can make zero-emission, zero-incident manufacturing possible.

In automated manufacturing, Big Data can help reduce defects and control costs of products. By tracking every detail about every part that goes into a product, from its original manufacturer, to where it was stored, to when it was installed, the data bank lets manufacturers retrace problems for better resolution. Monitoring defect ratios and on-time delivery can help with supplier selection and performance assessment.

Inside the factory, having the ability to utilize the mass of data on orders and machine status allows production managers to

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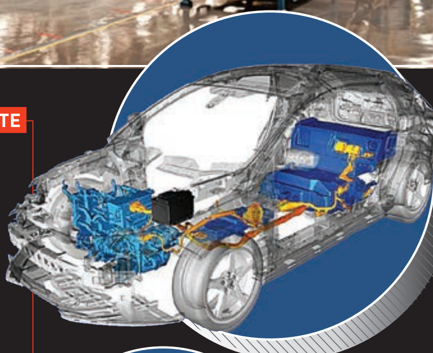
RAYTHEON CO.
www.raytheon.com

HEADQUARTERS: Waltham, Mass.
FOUNDED: 1922, as the American Appliance Co.
EMPLOYEES: 68,000.
REVENUES: $24 billion.

Raytheon is an international aerospace and defense company, whose products range from large-scale radars to cybersecurity technology. Its four principal business units are Integrated Defense Systems; Intelligence, Information, and Services; Missile Systems; Space and Airborne Systems.

PROGRESS OF AUTOMATION

Automation makes factories more efficient and therefore competitive, so the trend must be for more. Increasing intelligence of machinery and production lines decreases the need for human intervention in manufacturing processes. More and more, factory jobs don't require use of the hands as much as use of the mind.



CARS THAT COMMUNICATE

Sensors in each Ford Focus Electric produce streams of data while the car is driven and when it is parked. Not only is the driver informed, but Ford and others can analyze the information to improve the vehicle and to deal with issues like placing charging stations or avoiding grid overload.

VISUALIZING BIG DATA

A graph tracks how much energy is produced by more than 700 GE gas turbines over a two-week period. Each flash represents a turbine turning on at some location in the world. The wheel is arranged according to capacity of the turbines. The height of the graph represents the maximum output of each turbine.

DIGITAL ASSISTANTS TO WADE THROUGH IT ALL

THE EXPONENTIAL INCREASE IN THE VOLUME, VARIETY, AND speed of data generated by simulations, sensors, and other sources is expected to continue in the coming years. The data generated by large-scale simulation is predicted to reach terabytes per second. There is a need for developing novel intelligent software agents, or cybernetic assistants, to harness the power of BigData, and to enhance the productivity of the engineering workforce. They can help in crowd sourcing, and collaborative inventions, resulting in pushing the limits of what is possible for engineering systems.

The cybernetic assistants combine machine learning, natural language understanding, and novel modalities of human interaction to complement human intellect in new ways. Cybernetic assistants can leverage Big Data analytics tools and computational knowledge technologies developed by the research teams at the IBM Watson project, Wolfram Alpha, and other organizations.

They can exploit the new types of predictive search facilities for dynamic applications, where information is flowing continuously. An example of predictive search facilities is the MindMeld developed by Expect Labs. It is a smart phone app that listens to conversations and searches for related material on the internet. As Expect Labs describes it: "As your conversation changes, MindMeld continuously finds and displays relevant pictures, videos, articles, and documents so that any information you may need is at your fingertips."

The cybernetic assistants may eventually provide specific answers to questions and summary reports on any subject, or recommend a course of action in addressing a problem. In addition, the virtual assistants will have the capability of tracking every action that the users make on a computing device, and through the use of state-of-the-art sensors (such as gaze-tracking cameras, touchscreens, and gesture detection) and predictive analytics tools, deliver information without the users needing to ask. ■

big

optimize operations, factory scheduling, maintenance, and workforce deployment.

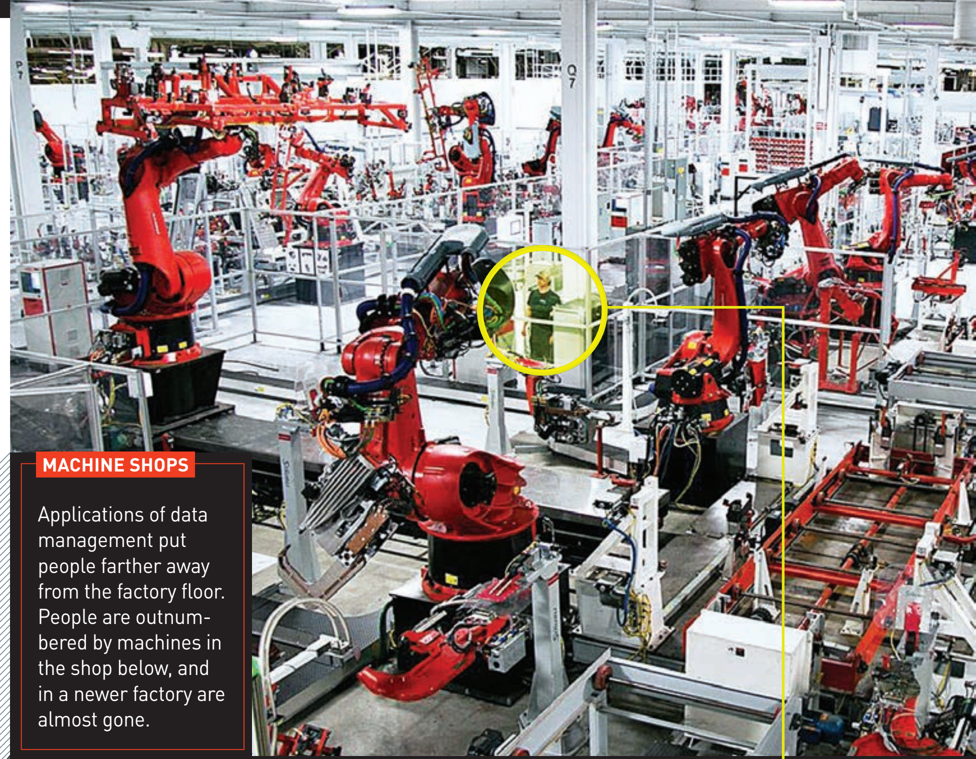
A number of developments under way now aim to realize the greater potential of Big Data in smart manufacturing.

The Smart Manufacturing Leadership Coalition, officially incorporated as a non-profit organization in July 2012, aims to overcome the barriers to the development and deployment of smart manufacturing systems. The coalition's members include stakeholders from industry, academia, government, and manufacturing. The organization supports development of "approaches, standards, platforms, and shared infrastructure" that will encourage adoption of smart manufacturing by providing easy access, lowering cost, and resolving serious technological barriers found in today's manufacturing environment.

Teams of members are currently developing a shared, open-architecture infrastructure called the Smart Manufacturing Platform that allows manufacturers to assemble a combination of controls, models, and productivity metrics to customize modeling and control systems, making use of Big Data flows from fully instrumented plants in real-time. The development of a smart manufacturing platform is intended to help management across the manufacturing ecosystem, and to forecast activities that, for example, can be used to slash cycle times and reduce the risks of product development.

The infrastructure will enable third parties to develop networked industrial applications that provide tools for resource metering, automated data generation, intuitive user interfaces, and Big Data analytics. Enhanced computing power, an enabling open-architecture infrastructure, and software advances can make data management invisible to the engineer, the bulk of it happening in the background.

Applications do not end at the factory. Future products can be outfitted with sensors that connect to the cloud, enabling after-sales service offerings. There could be an option in cars, for instance, that will alert drivers or service centers when maintenance is needed. Data showing how customers use products can suggest improvements in design or manufacturing.



MACHINE SHOPS

Applications of data management put people farther away from the factory floor. People are outnumbered by machines in the shop below, and in a newer factory are almost gone.

MANUFACTURING WILL STILL NEED PEOPLE.

AUTOMATED MACHINES REQUIRE SOMEONE TO SERVICE THEM. SOME MACHINE OPERATORS WILL BECOME MACHINE MINDERS, WHICH OFTEN CALLS FOR A BROADER RANGE OF SKILLS.

Smart manufacturing is likely to evolve into the new paradigm of cognitive manufacturing, in which machining and measurements are merged in order to form more flexible and controlled environments. When unforeseen changes or significant alterations happen, machining process planning systems receive on-line measurement results, make decisions, and adjust machining operations accordingly in real time.

It is conceivable that one day machines and processes in a factory will be equipped with capabilities that allow them to assess and increase their scope of operation autonomously. This changes the manufacturing system from a deterministic one, where all planning is carried out off-line, to a dynamic one that can determine and reason about processes, plans, and operations.

Because of smart and dexterous robots, and novel

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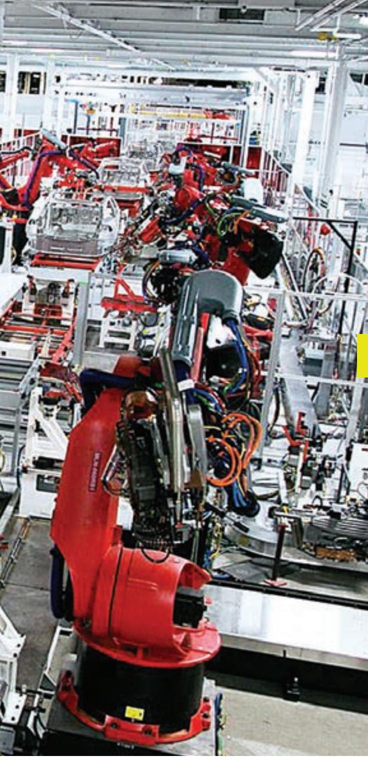
FANUC CORP.
www.fanuc.co.jp

HEADQUARTERS: Japan: Oshino-mura, Yamanashi Prefecture. **United States:** FANUC America, Rochester Hills, Mich.

FOUNDED: 1956

REVENUES: ¥489.4 billion ($5.1 billion).

FANUC designs and manufactures automation technology for all stages of factory production lines.



LEARN MORE

For more information on Big Data, go to:

http://www.aee.odu.edu/bigdata

The website, created as a companion to this *Mechanical Engineering* magazine feature, contains links to material on Big Data information, current activities, technologies and tools, educational and research programs, including Big Data University.

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FORD MOTOR CO.
corporate.ford.com

HEADQUARTERS: Dearborn, Mich.
FOUNDED: 1903
EMPLOYEES: 175,000
REVENUES: $134.3 billion.

Ford, one of the traditional Big Three automakers in the United States, has worldwide operations that include 65 factories. The company sells more than 5.5 million vehicles a year.

manufacturing technologies, many new production methods will require fewer people working on the factory floor. For example, FANUC Robotics, a Japanese producer of industrial robots, has automated its newest tool plant to the point where it can run mostly unattended for 700 hours. Many other factories use processes such as laser cutting and injection molding that operate without human intervention.

Manufacturing will still need people. This is because automated machines require someone to service them. Some machine operators will become machine minders, which often calls for a broader range of skills.

Throughout history, new tools which make possible new kinds of measurements and observations have led to technological and scientific revolutions. Microbiology was born in 1676 when the microscope discovered the existence of microorganisms in a drop of water.

The emerging tools being developed to process and manage the Big Data generated by myriads of sensors and other devices can lead to the next scientific, technological, and management revolutions. The revolutions will enable an interconnected, efficient global industrial ecosystem that will fundamentally change how products are invented, manufactured, shipped, and serviced. ME

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TOOLS AND TECHNOLOGIES

Traditional data warehouses are not able to handle the processing demands posed by Big Data. As a result, a new class of technology has emerged.

The Apache Hadoop, for example, is an open-source platform that can be used for processing a complex mixture of data, including log files, pictures, audio files, communications records, or e-mail, regardless of native format. Hadoop keeps all the data online for real-time interactive querying, analysis, visualization, and business intelligence. It is now widely used across industries, including telecom, healthcare finance, and entertainment, and in government.

GE uses Hadoop software to manage time-series data, allowing it to scale data across multiple nodes, helping to manage the influx of tiny pieces of data that come in almost constantly.

Microsoft has developed a suite of tools for Big Data applications, including Microsoft Upstream Reference Architecture created to meet the needs of the oil and gas industry. It provides a bridge between the needs of the business and the Microsoft technology that supports IT. It offers statistical and analysis packages for data mining, discovery, and reporting for diverse information consumers.

It also integrates decision-making processes and results to create and retain information relationships, history, and context.

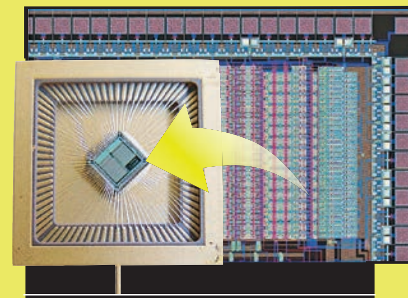
IBM developed predictive analytics products for a variety of applications. The IBM platform covers system management, application development, and visualization and discovery. Several automakers use the platform in projects to develop and deploy connected car solutions that enable vehicle-to-vehicle, vehicle-to-driver, and vehicle-to-infrastructure communication in real time.

Fast, Google-like search of data can be made by using software systems like Clusterpoint. BigQuery is a cloud-based interactive query service, developed by Google for massive datasets.

Cisco Industrial Smart Solution is a portfolio of validated IP-networking technologies that connects factory automation and control systems to enterprise business systems.

Grok, a cloud-based service company, formerly known as Numenta, is building a neuroscience-inspired engine to find patterns in large data streams and to generate practical predictions in real time.

A number of attempts are being made to develop cognitive computers that can effectively process Big Data, through emulating the human brain's billions of interconnections, computing efficiency, size and power usage without being programmed. These attempts take advantage of recent focus on understanding the human brain's ability to learn, recognize patterns, adapt, and respond to changes in the environment. They include the Defense Advanced Research Project Agency's Systems of Neuromorphic Adaptive Plastic Scalable Electronics (SyNAPSE) Project. The goal of the project is to develop electronic neuromorphic machine technology that scales to biological levels. Researchers include teams from IBM, Hughes Research Labs, and Academic institutions. ■



PROCESSING HARDWARE
A chip designed by ETH Zurich and the University of Zurich is comparable in size, speed, and energy consumption to the human brain.

ALMOST LIKE THINKING In 2011, IBM demonstrated a building block for a chip architecture based on a scalable and configurable network simulating brain activity.