Theme in short – Goodbye to the industrial age

▶ The Industrial Revolution started over 250 years ago, triggered by the use of new technology on a broad scale. ▶ We are now looking at new ways to manufacture, distribute and consume things. These changes will have a profound impact on society, and will prove no less revolutionary than those that formed the industrial society.
CONCLUSION ▶ Get used to the following concepts: "functional products," "smart products" and "digitally producing individuals." ▶ Get used to thinking of products as not entirely physical things: society at large needs to adapt its communications infrastructure to support the digital revolution.

Connectivity will **radically change** the way we think about products

Goodbye to the industrial age

ILLUSTRATIONS Gustav Dejert

Why sell the product if you can sell the function instead? Today, there is a strong push toward so-called industrial product-service systems, total-care products, functional sales or functional products. But selling a function brings complexity.

"Connectivity is thus a crucial issue; ***adequate provision must be made for communication*** from deep within a mountain or a jungle, for example, and the monitoring techniques and technologies used must be adapted to the circumstances."

functional products
Definition
the development of integration between hardware, software and service

INCREASING COMPETITION from players that have the advantage of lower labor and production costs forces many corporations to "rethink" what they are doing. Corporations with a global presence have leaders who can sense where the existing offers continue to work, and where new offers and ideas are required in order to stay in business. Changing or adding new business models can be quite straightforward and business-as-usual. However, in some cases it can be far from easy, and may require a transformation of the corporation and its delivery process.

For corporations that are used to producing and selling products, services or services bundled with products, taking the step toward selling a function may be attractive. To actually sell a function, with an agreed-upon availability level, where the provider retains the ownership and the customer pays for the delivered function only, requires additional thinking and preparation. It necessitates a life-cycle perspective that encompasses risk management, finance, design and development, support and maintenance, and access to competence and skills, for example.

Today, many corporations and research groups strive to find the keys to new business models such as industrial product-service systems, total-care products, functional sales or functional products. These business models are all related in the sense that they all enable a revenue increase from soft parts such as services, knowledge and know-how – often extending existing hardware product sales. These business models vary in terms of their sophistication and constituents, although, compared with selling products combined with services, selling a function brings additional complexity.

The additional sophistication allows for additional revenue and intimate long-term relationships between providers and customers, requiring the creation of a clear win-win situation where the provider needs to be able to charge for taking increased risks as well as for retaining product ownership.

SELLING A FUNCTION – WHAT IS REQUIRED?

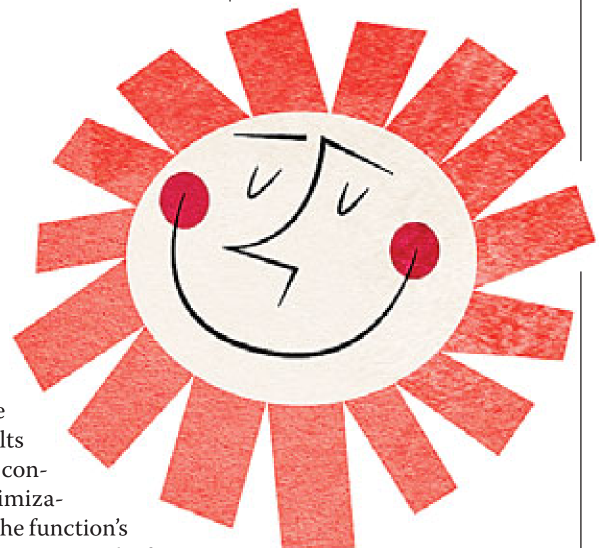
To be able to sell a function and manage the risks involved, there is a need, during the design and development phase, to model the level of product availability versus cost in order to determine if and how the function should be sold. The product might consist of a hardware core supported by an integrated support system. A function must also be designed and developed so that its way of operating may be monitored, which requires the possibility to extract data pertaining to the status and usage of the function. The software required can be seen as a standalone constituent or as an integral part of the hardware and support system.

Later on, as a function is delivered to customers, there is a need for providers to monitor the function in order to honor the level of availability agreed upon. The idea is not only to monitor the operation but also to be able to find the root cause of any problem that arises, and not just manage the symptoms, which will recur unless properly managed.

BIG DATA EXCITEMENT

The time taken to repair something can be shortened by completing the diagnosis before a service engineer arrives at the site. To monitor an instance of a function requires intelligent analysis of complex questions. Data streams originating from sensors or other forms of data extractors must be managed – preferably in real time – to be able to react before any serious breakdowns occur. Often, if you know what to look for, there are signs indicating that something will break or needs to be maintained. However, identifying the causal relationships between different monitored parameter sets – for example, imminent hardware failure or trends signifying future faults – requires a structured analysis by the function provider. If such cause-and-effect relationships may be identified, monitoring can allow for needs-based maintenance instead of planned maintenance, optimizing the costs as well as enabling the planning of maintenance based on a known maintenance need.

The above issues are of great interest for professionals interested in the telecom industry, as very large amounts of data (big data) must be monitored and analyzed. This becomes even more exciting if you think a bit bigger: a machine (as part of a function delivered) may have 10 to 300 sensors, each generating signals ranging from 1 to 10,000Hz.



An example is a case from Hägglunds Drives AB Bosch Rexroth, which sells hydraulic motors and hydraulic drive systems for use in the mining, pulp and paper industries. If a customer wants to buy a function instead of a product with services, the function needs to be monitored to secure the agreed-upon level of operational availability. The monitoring would require analysis of some 50 to 60 parameters, as well as relations between various parameters – preferably in real time – allowing for both preventive (needs-based) and reactive maintenance, and for the identification of the origins of any problems. If the functional business ramps up, a global corporation may have hundreds or even thousands of instances of a function running simultaneously. Thus, the amount of data can be huge, and the need for real-time analysis will require adequate computing power.

Doing the math reveals that this is not a simple issue of having a number of people in a monitoring office looking at a few screens, but a scalability problem. The interesting bits of data have to be singled out from the vast volumes of data passing quickly by as data streams. Serious computing power is required to be able to analyze enormous amounts of data in real time.

Combining local processing with further processing by data centers (with massive parallel computers) or cloud computing (allowing elasticity) fits well in this context. The sheer amount of data makes it more or less impossible to store all data passing by; but that is not necessary, since the interesting bits of a data stream can be saved and further analyzed.

A DECISION SUPPORT TOOL

In order to be able to predict machine (hardware system) and support system function (maintenance activities, manuals, spare parts, tools, logistics and so on) availability, both must be properly described. A sensible approach is to model, simulate and eventually optimize the machine and the support system concurrently, simultaneously taking into account their maintainability, reliability and thus availability. If availability is known through modeling, there is still the challenge of predicting exactly when a function may become unavailable. The use of simulation frameworks by means of data streams originating from prototypes, testing or actual monitoring of equipment in operation allows for the discovery of areas where faults are likely to occur, as well as continuous improvements, optimizations and re-designs during the function's whole life cycle, from early design to end-of-life.

Several different modeling techniques are therefore of interest, and integrating these into the required functional product model is a challenge. However, the rewards for doing so are great, since such models may be used not only to describe reality but, more importantly, to decrease the development cost of new functions, to verify and validate equipment functionality, and to identify possible support-system bottlenecks. These models can, when working in conjunction with suitable monitoring techniques, also serve as a decision support tool, as well as a business-negotiation support tool.

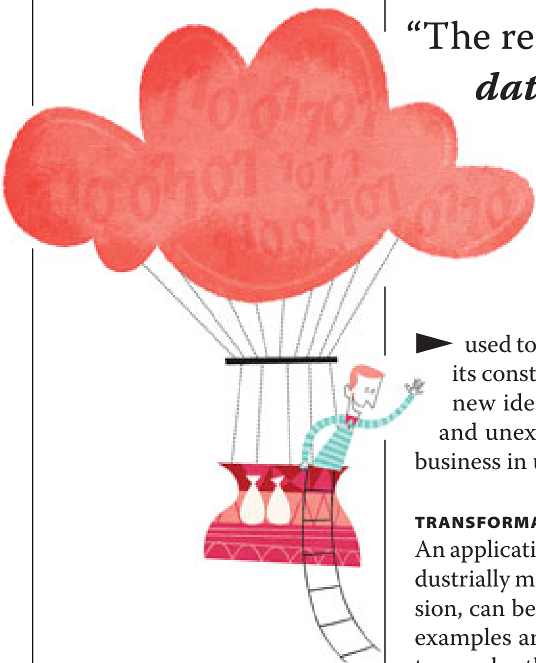
When a problem is indicated through modeling, trends may have been identified by monitoring. If a problem has already occurred, a mitigation plan is needed. The plan needs to be executed with the customer contract and agreed-upon level of availability in mind. The mitigation can range from a simple e-mail to the need for complex remote or on-site collaboration, application and data sharing involving the customer, service engineers and various specialists.

During the operational part of a function's life cycle, there is an opportunity for small and medium-sized enterprises contracted by the provider to provide specialist services remotely and or on site. Having adequate collaboration tools and knowing who to put on a mitigation team and when becomes very important in order to resolve any issues or problems in a timely fashion.

Connectivity is thus a crucial issue; adequate provision must be made for communication from deep within a mountain or a jungle, for example, and the monitoring techniques and technologies used must be adapted to the circumstances.

The monitoring and collaboration opportunities enabled by a function should further be ▶

▶ **THE TERM "POWER BY THE HOUR"** was coined by Rolls-Royce over 20 years ago to describe their performance-based contracts for engines and other avionics products that were sold to commercial airlines. According to Rolls-Royce, its Power By The Hour programs "provide the operator with a fixed engine maintenance cost over an extended period of time. **Operators are assured of an accurate cost projection** and avoid the costs associated with unscheduled maintenance actions."



> "The research has an Internet of Things approach, ***using data from sensors*** and actuators, for example, for modeling, simulation, design and development purposes."

used to improve and refine the function and its constituents throughout its life cycle, and new ideas gained from customer feedback and unexpected usage can open up for new business in untapped segments or markets.

TRANSFORMATION BY EXTENSION OR NEW DESIGN

An application of the above can be traditional industrially manufactured goods, which, by extension, can be sold as functions instead. Concrete examples are power-by-the-hour (jet engines), torque-by-the-hour (motors) or drilled-meters-per-hour (drills). However, it may be easier to develop a function from scratch instead of transforming existing products and services into a function. By designing features required from a function from the start, it is likely easier and less expensive to add – for example – data-extraction interfaces or sensors inside a motor. Adding sensors later on is commonly much harder and more costly, and it might not even be possible in many cases without carrying out expensive re-designs. For many organizations, this transformation can be the difference between being a follower or a market leader.

The distinction between leasing and selling a function may be illustrated by the following example. If you are leasing a car and it breaks down while you are driving it – unless it is very sophisticated and calls for help itself – you will most likely need to call for a truck to tow it away. If the car had been sold as part of a function, the monitoring service would have indicated that something was not as it should be before any severe damage occurred – damage that, in a worst case scenario, would cause the car to stop. The provider of the function would have contacted the user and, depending on the contractual agreement, either picked up the car while it was not in use and returned it when it was needed again, or provided a replacement car.

INTERNET OF THINGS IN AN INDUSTRIAL CONTEXT

In an industrial context, the Internet of Things involves machines, humans, business models, complex computations on data streams, scalable computing power and lots of data passing by in data streams. For many years, Computer Aided Design at Luleå University of Technology, Sweden – together with research partners such as the Uppsala University, Database Laboratory, and the Risk and Reliability Engineering at the University of Nottingham, UK – has been researching how functions or functional products can be developed and sold. The research has an Internet of Things approach, using data from sensors and actuators, for example, for modeling, simulation, design and development purposes. The Faste Laboratory, a VINNOVA Excellence Center at Luleå University of Technology, is the premier vehicle for the research, combined with other international projects such as the SmartVortex EU Integrated Project to achieve the momentum and volume needed to remain visionaries within the field. ●

AUTHOR

LENNART KARLSSON is Professor of Computer-Aided Design at Luleå University of Technology (LTU) in Sweden. His research interests include simulation-driven product development, modeling and simulation in the fields of applied mechanics and availability, and the development of functional products.
(lennart.karlsson@ltu.se)

AUTHOR

JOHN LINDSTRÖM is an Assistant Professor at Luleå University of Technology (LTU) in Sweden. His work targets product-development processes, modeling and simulation in product development, and information security mainly in relation to business continuity, availability and reliability. He has 15 years' industrial experience from various industries in management and specialist positions, and joined LTU in 2009.
(john.lindstrom@ltu.se)

AUTHOR

MAGNUS LÖFSTRAND is an Assistant Professor at Luleå University of Technology (LTU) in Sweden and works with projects concerning modeling and simulation of system availability and cost, and the monitoring of industrial systems through a data stream management approach.
(magnus.lofstrand@ltu.se)