Featured Articles

Digital Sensing Technology for Visualizing Sites

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OVERVIEW: Hitachi believes that the utilization of sensing technology is effective for meeting the various needs of society, and that the concept of using digital sensing to visualize sites is particularly important. Digital sensing can create new value by converting site data obtained from sensors into valuable site information, analyzing site challenges in the IT space, and using the results to control the site. This article discusses duct monitoring in factories as a specific example of digital sensing. It also presents a maintenance-free sensor node as an example of sensor node technology that implements digital sensing.

INTRODUCTION

HITACHI believes that the utilization of sensing technology is effective for meeting societal needs such as ensuring a safe and secure society, dealing with a decreasing birthrate and an aging population, and taking measures to fix aging infrastructure. Hitachi aims to assist in solving on-site challenges by using sensor and signal processing to identify various conditions at the site, and using the results to provide the appropriate control processes. In doing this, Hitachi aims to create and deploy an Internet of Things (IoT) services and solutions business that meets the needs of society.

This article looks at a concept of digital sensing that Hitachi considers key, along with examples of its implementation.

HITACHI'S AIMS FOR DIGITAL SENSING

In the past, the use of physical quantities in real space measured by sensors stopped at their use in operation monitors of site equipment or in predictive diagnostics, after receiving simple processing in IT space. However, sensing in the IoT era will use artificial intelligence (AI) or analytics in the IT space for analysis of real-space physical quantities, and controllers will use those results to perform real-space control. Hitachi is particularly aiming for digital sensing that will convert real-space physical quantities obtained by sensors into compact valuable information enabling easy analysis in the IT space. Valuable information is site information that has become visualized (see Fig. 1).

For example, the waveforms of sound waves emitted by elevators (real-space measurement data) can be converted into valuable information like the problem location information, image data captured by vehicle-mounted cameras can be converted into pedestrian position information, and electrical current waveform data from a mega solar power plant can be converted into failure location information. Smarter site information can be obtained by developing valuable information extraction technology that calculates correlations and filters measurement data obtained from multiple sensors.

Since the signal processing done to obtain valuable information will need to be site-specific and enable real-time processing of large volumes of data, it will be done at the site using distributed edge computing. These edge computing-driven preprocessing and IT-space analytics tool groups will need to be optimally coordinated.

As described above, the extraction of valuable site information using digital sensing could play a central role in IoT-era sensing that analyzes the challenges at sites and controls sites in the IT space based on site data.

DIGITAL SENSING IN FACTORIES

In responding to the needs of society, factories are being called on to improve productivity, reduce energy costs, and improve safety. The challenge for accomplishing this is how to identify the status of existing equipment (such as instruments and ducts), equipment that cannot be shut down, and equipment in high or other inaccessible locations. For example,

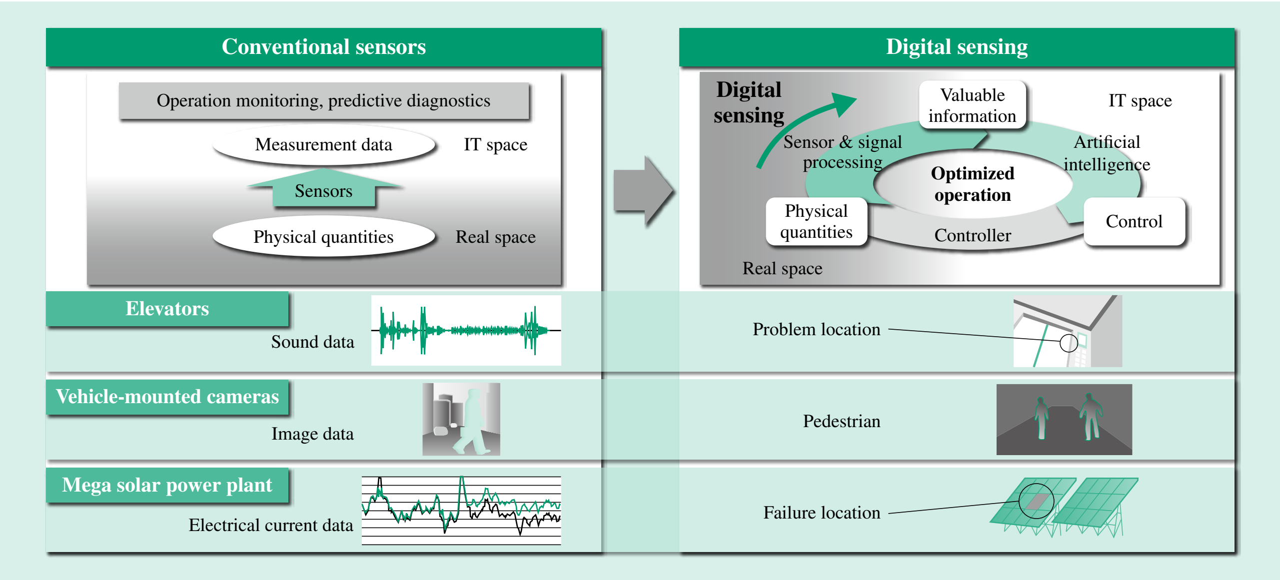

Fig. 1—Concept of Digital Sensing.
Digital sensing converts site data obtained by sensors into valuable site information. Digital sensing creates new value that meets the needs of society by analyzing site challenges in the IT space and using the results to control the site.

on one hand, progress is being made in popularizing the visualization of power consumption of factory equipment, in addition to the momentum on reducing CO_2, on the other hand however, the visualization of energy consumption of gas-fired factory equipment such as boilers, etc. is not sufficiently widespread. In addition to the high price of gas flowmeters, this difference in popularization is attributable to the fact that flowmeters require both electrical work and duct work for installation, and therefore, multi-unit monitoring requires a massive investment.

In response, Hitachi is looking into a digital sensing application that uses duct vibrations as a method of identifying gas duct states at comparatively low cost. To extract valuable site information from measured duct vibration data, the application can utilize correlational analysis and filtering with the outputs of other sensors (see Fig. 2).

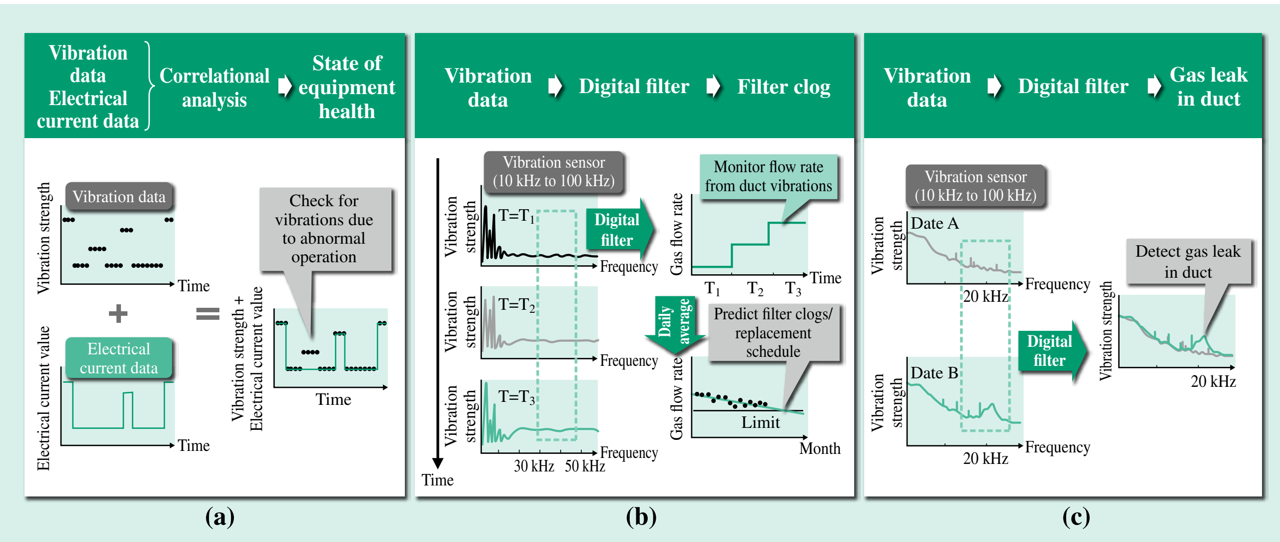

Fig. 2—Signal Processing for Extracting Valuable Information.
(a) shows how correlations among the outputs of multiple sensors are used to extract abnormal equipment operation. (b) shows how filtering is used to extract appropriate filter replacement schedules. (c) shows how filtering is used to extract valuable information such as signs of gas leaks in a duct.

In Fig. 2 (a), current sensors measuring current consumption with equipment are used in conjunction with sensors measuring duct vibrations, and abnormal equipment operation is detected when a time slot is found to contain abnormalities in the relation between the vibration strength and electrical current values obtained. This approach can extract valuable information by calculating correlations among the outputs of multiple sensors. And, in Fig. 2 (b), the gas flow rate of a duct is calculated in a time series by using vibration sensors to obtain the vibration spectrum of the duct in a time-series, and using filters to extract specific frequency components that will serve as indicators of the gas flow rate in the duct. Changes in the daily average can be used to predict the filter clog rate and an appropriate replacement schedule. In Fig. 2 (c), duct gas leaks can be detected by using filters to extract particular frequency components from the vibration spectrum of the duct. Proper filtering based on domain knowledge is an effective way of obtaining valuable information.

To test the hypothesis that vibration sensors can be used to identify duct states, Hitachi carried out an actual factory test(1). Fig. 3 (a) shows the results from a vibration spectrum measured in a time series by a sensor installed in the gas duct of boiler equipment. The plot of the change over time in the vibration components from 40 kHz to 50 kHz shows that vibration strength changes in response to changes in boiler combustion state. The inferred reason is that the speed of the turbulence in the duct increases in proportion to the gas flow rate and causes the duct to vibrate.

This testing has shown that duct vibration measurement and proper filtering can be used to infer gas flow rates in ducts without the need to install equipment, enabling valuable information to be obtained, such as equipment operation states and energy consumption.

Fig. 3 (b) shows the results of the vibration spectrum measurements for two ducts in the same factory, one duct that does not have a gas leak, and one duct that does. The results show that, when a duct has a gas leak, a broad peak is generated in the 20 kHz to 40 kHz frequency range. This test shows that valuable information, such as signs of gas leaks in a duct, can be obtained through measuring the vibration of the duct and proper filtering.

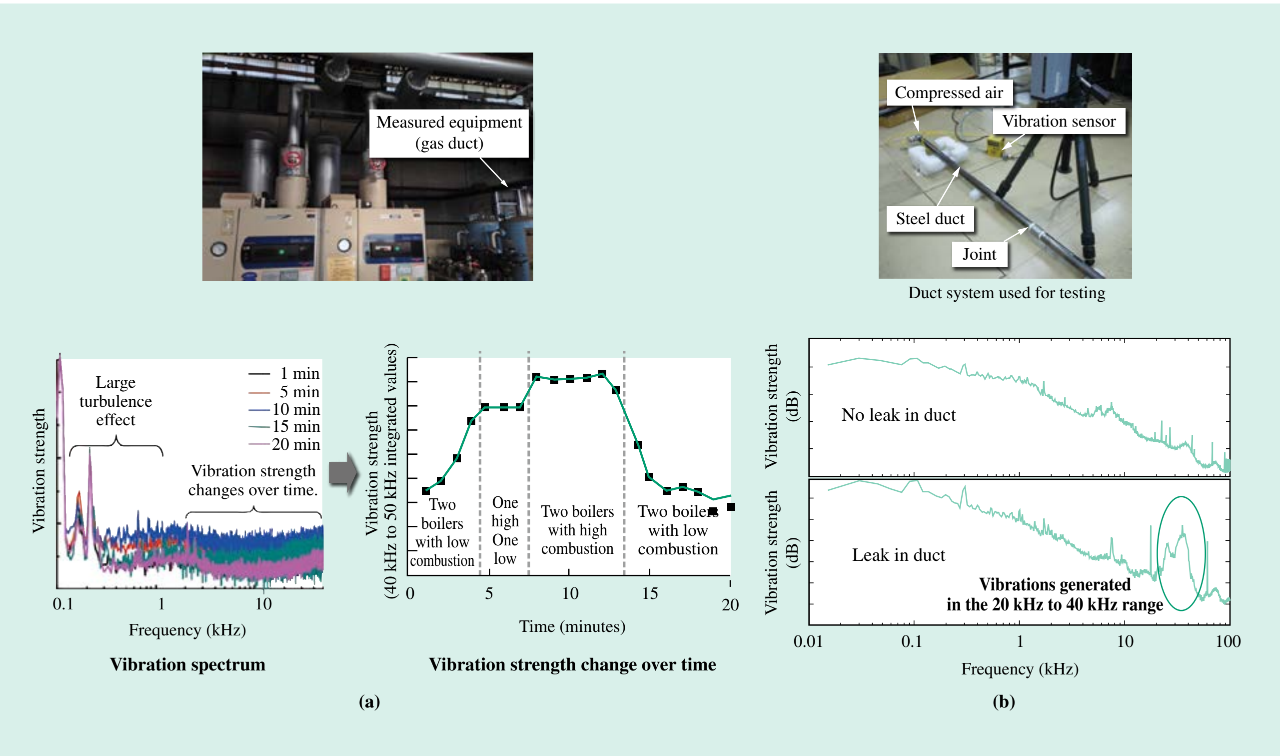

Fig. 3—Examples of Digital Sensing in a Factory.
(a) shows how measuring duct vibration and filtering make it possible to estimate the gas flow rate in a duct, and to extract valuable information such as equipment operation states and energy consumption. (b) shows how valuable information, such as detecting gas leaks in a duct, can be obtained through measuring the vibration of the duct and filtering.

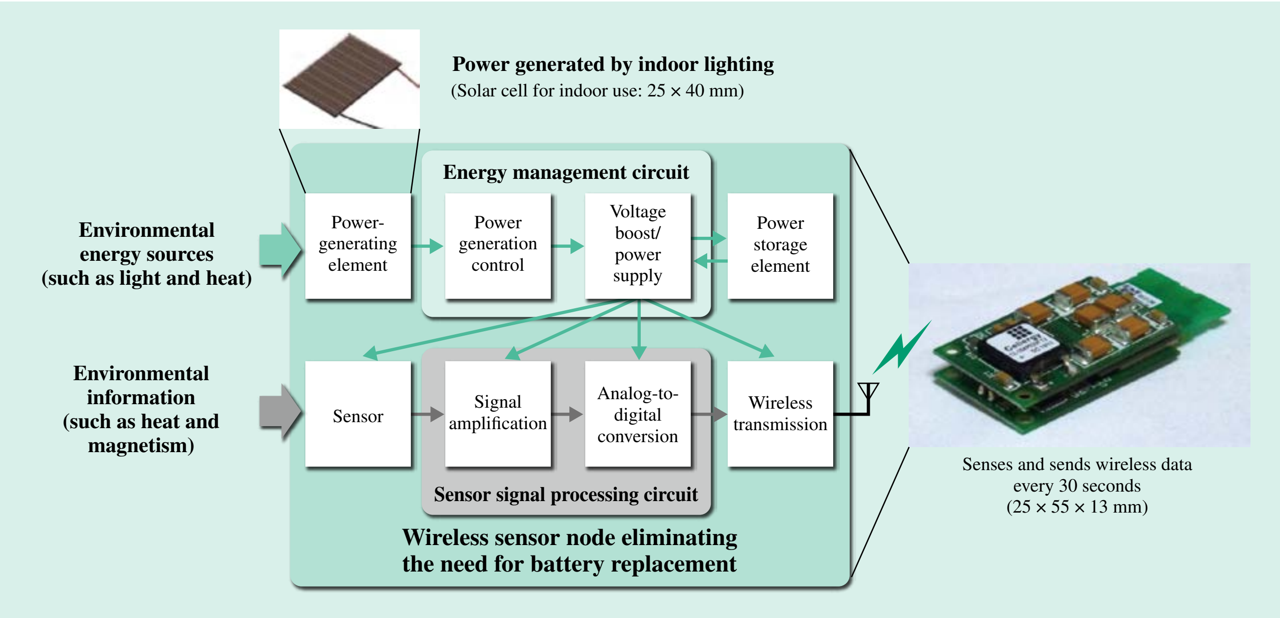

Fig. 4—Maintenance-free Wireless Sensor Node.
This sensor node can provide sensing indefinitely while running on indoor lighting, by having a circuit that manages minute amounts of energy, and a sensor signal processing circuit with low power consumption.

MAINTENANCE-FREE SENSOR NODE

To make digital sensing a reality, multiple sensors need to be installed at a site, and the data they measure needs to be collected. To eliminate the maintenance burden of replacing batteries, it is recommended that sensor nodes are able to run on a minute amount of environmental energy, such as the light in a dim factory, and they should also be able to send data wirelessly, eliminating the need for wires.

To meet these needs, Hitachi has developed a wireless sensor node that can run on indoor lighting. The sensor node has an energy management circuit that can efficiently collect and use minute amounts of environmental energy, and a high-precision, low-power sensor signal processing circuit built in (see Fig. 4)[(2), (3)]. A power-generating element of a few centimeters in size can be mounted in the sensor node. This element can supply energy ranging from only a few microwatts (μW) up to a maximum of 100 μW, so the energy management circuit monitors the retained voltage of the power storage (capacitance) elements of the blocks in the sensor node, and supplies power to them only when their retained voltage values have fallen below the preset level. This configuration enables the power-generating element to provide the essential power storage for the power storage elements by using periods during which the blocks consume no energy (such as when signals are not transmitted). As a result, the power-generating element has the ability to supply a minute amount of energy. The sensor signal processing circuit has a built-in high-resolution, low-power analog-to-digital converter circuit with digital correction, and achieves high precision (margin of error 0.01%) and low-power operation that enables the energy management described above.

The sensor node developed by Hitachi can start in about 1/50 of the amount of time needed by a conventional sensor node, and can run on as little as about 1/10 of the light (about 70 lux). In this way, it was able to demonstrate a sensor node that does not require battery replacement or wiring, and has practical functionality and precision.

The sensor node technology described above has been used to create a prototype sensor node that measures the current consumption of industrial equipment, proving that it can be used in a factory environment. In the future, Hitachi plans to utilize this technology in various industrial equipment monitoring applications, and in the use of beacons to monitor the movement of people.

CONCLUSIONS

This article has described the concept of digital sensing, examples of its use in factories, and sensor node technology. In the future, Hitachi would like to apply this digital sensing at many sites to assist in solving the challenges they face.

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