OKI's Sensing Technologies to Strengthen AI Edge Computing

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The Sustainable Development Goals (SDGs) have gained worldwide recognition, and as development rapidly progresses towards fulfilling its 17 goals and 169 targets, there is an increasing need for various sensing technologies to digitize the real world. At OKI, the seven social issues of "aging infrastructure," "natural disasters," "transportation issues," "environmental issues," "labor shortages," "labor productivity," and "infectious diseases," have been set forth in its materiality (important issues) details, and the priority technology for solving those issues is the "AI edge." "Sensing" is one technological domain that strengthens this "AI edge," and OKI is advancing research and development of its original sensing technologies of optical, image, and sound.

In this article, OKI's initiatives in the sensing domain is first explained, which is followed by an introduction of three sensing technologies namely "advanced photonic sensors," "advanced real-time AI vision" and "highly reliable fusion sensing." Specifically, their supposed solutions to on-site issues and the features of each technology are discussed.

Initiatives in Sensing Domain

OKI's priority technology "AI edge" refers to a group of technologies that accelerate digital transformation (DX) and contribute to the advancement of social infrastructures. Five technological domains have been defined as leading domains for strengthening this "AI edge" (**Figure 1**).

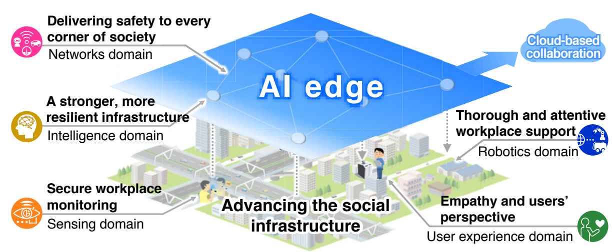

Figure 1. Priority Technologies to Strengthen AI Edge

Initiatives in the "sensing domain," which is one of those domains, are outlined in **Figure 2**. OKI's "sensing" aims to solve critical on-site issues where errors or suspensions

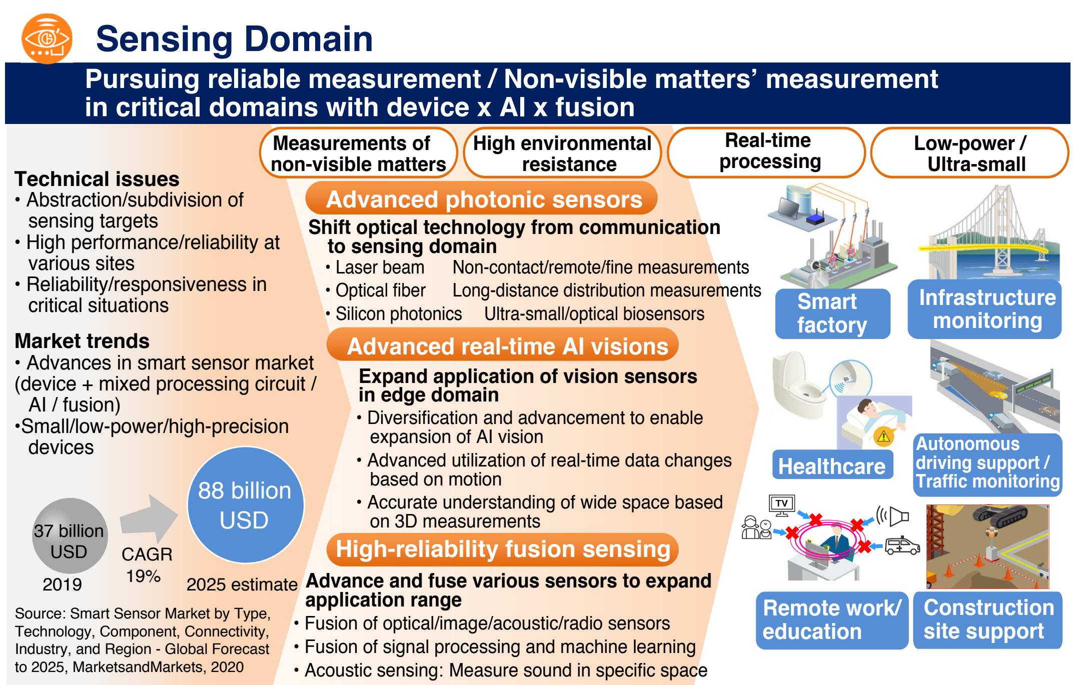

Figure 2. Initiatives in Sensing Domain

are unacceptable (e.g. in transportation, construction and manufacturing fields) using high-infrastructure-grade technologies that ensure performance and availability. These technologies precisely supports OKI's key message, "Delivering OK! to your life."

There are various sensing targets for solving critical on-site issues including equipment vibrations, abnormal traffic conditions, and the presence of viruses. The operating environment also varies from rainy to snowy weather. Additionally, as real-time processing and power reduction are essential to edge computing, development of lightweight AI and sensing devices with low-power consumption is also needed. In response to such challenging on-site requirements, "measurements of non-visible matters," "high environmental resistance," "real-time processing," and "low-power / ultra-small" are values set to be offered from OKI's "sensing." While ensuring competitiveness, OKI is proceeding with research and development on three topics of 1) "advanced photonic sensors" related to optical sensors, 2) "advanced real-time AI visions" related to 2D and 3D vision, and 3) "high-reliability fusion sensing" related to sensor fusion.

Advanced Photonic Sensors

OKI is applying its high-speed optical communication technology cultivated in the optical communication business to sensing. Specific examples include "optical fiber sensing technology[1)]" that uses optical fiber as a sensor, "laser vibration sensing technology[2)]" that measures the vibration of an object with a laser, and "optical bio sensing technology[3)]" that uses silicon photonics as an ultra-small biosensor. These technologies are introduced below.

(1) Optical Fiber Sensing

Health monitoring of reinforced concrete bridges is one measure against "aging infrastructure," but initial crack detection is an issue. To solve this issue, an optical fiber sensing technology that uses the optical fiber itself as a sensor head to measure physical quantities such as temperature, strain, and vibration is being developed. The Brillouin scattered light generated when light propagates through an optical fiber changes its central frequency according to partial changes in temperature and strain on the optical fiber. Therefore, detection of this frequency change enables distributed temperature/strain measurement along the optical fiber.

OKI has developed its own signal processing (Self Delayed Homodyne Optical Fiber Sensor) inspired by a differential detection scheme that is very common in optical communication technology (**Figure 3**). It is significantly faster and has better spatial resolution than conventional Brillouin Optical Time Domain Reflectometry.

The technology enables real-time measurement of temperature and strain with a spatial resolution of 10cm and a measurement range of 500m, and it is an effective technology for early detection of small cracks on roadways.

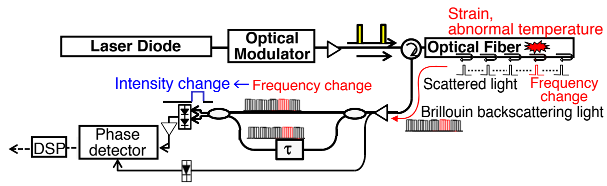

Figure 3. Device Configuration of Delayed Homodyne Optical Fiber Sensor

(2) Laser Vibration Sensing

One measure against "labor shortages" in the smart factory field is the detection of anomaly signs in factory equipment. The issue here is measuring abnormal vibration due to initial failure at the component level. To solve this issue, a laser vibration sensing technology is being developed. The technology irradiates the target object with pinpoint laser, and accurately measures the vibration amplitude and vibration frequency of the object from the return light whose wavelength has changed due to the Doppler Effect.

OKI has developed a multi-point laser vibrometer with a high S/N ratio by applying the digital optical signal processing cultivated in digital coherent systems (**Figure 4**). Features include multi-channel optical switches and long-distance optical fibers. It is possible to measure more than 100 points, a range of more than 100m, and frequency from several Hz to several hundreds of kHz with a single unit. Its contactless nature enables the measurement of moving objects and high/low temperature objects, etc., which was difficult with conventional contact-type vibrometers.

The technology is effective in measuring abnormal vibrations (several tens of kHz) resulting from initial failure at the component level.

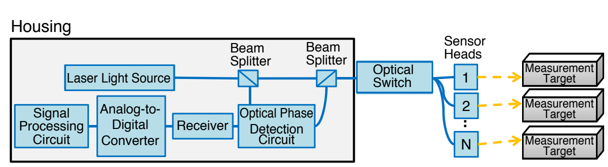

Figure 4. Multi-Point Laser Vibrometer Configuration

(3) Optical Biosensing

In the medical/healthcare field, virus and disease testing using blood or urine is one measure against "infectious diseases." Issues here include real-time virus testing and miniaturization of testing equipment. To solve these issues, OKI is developing an optical biosensing technology that utilizes silicon photonics and other optical technologies to perform advanced analysis related to biotechnology such as testing samples for presence or absence of viruses.

Silicon photonics technology developed for optical communication has been applied to an ultra-small biosensor that captures the change in liquid concentration caused by antigen-antibody reaction on the optical waveguide as a change in resonance wavelength. This enables highly accurate real-time measurements (**Figure 5**).

Compared to conventional optical biosensors such as SPR (Surface Plasmon Resonance), the silicon photonics sensor chip has an extremely small size of several mm^2. As a result, the device can be made extremely small, and also allows the device to be arranged in an array for simultaneous multi-measurements.

The technology is effective for real-time virus testing and miniaturization of testing devices.

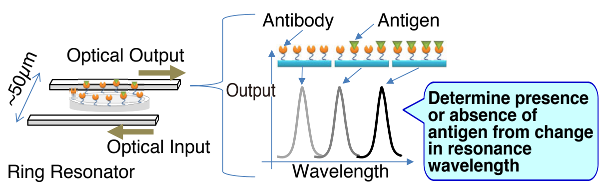

Figure 5. Operating Principle of Optical Biosensing

Advanced Real-Time AI Vision

OKI has been working with image recognition for over 30 years, and it has developed highly environmentally resistant, lightweight, and high-speed technologies, such as face recognition for mobile devices and vehicle detection for traffic volume measurement, capable of operating in the edge domain. Making use of past achievements, OKI is aiming to advance real-time AI vision in video image and 3D data processing, and it is proceeding with the development of "image sensing technology[4]" for 2D images from cameras and "3D-LiDAR sensing technology[5]" for 3D point cloud obtained from 3D-LiDAR.

(1) Image Sensing

Improving factory efficiency through DX is extremely important to increase "labor productivity" in the smart factory field. One of the targets is improvement of quality in manual assembly process. In such process, there are concerns about deterioration in manufacturing quality due to the declining number of skilled workers. Therefore, it is necessary to make worker's know-how and techniques inheritable through digitization. In order to solve this problem, OKI is developing image sensing technologies such as object detection, object identification and anomaly detection.

Particularly, focus was placed on human/worker action recognition from video streams. OKI is developing a three-layer action recognition technology in which every layer represents different level of recognition capability of the targeted input (i.e. from fine-grained image feature extraction to coarse-grained explainable action representation as shown in **Figure 6**). Initially, the first layer extracts human pose information as necessary features for later action classification. Next, the second layer uses Temporal Convolutional Networks (TCN) to identify short-time actions. Finally, in the third layer, time-series results from the second layer such as action's order and duration are used to judge the whole process' correctness. Using a three-layer saparable action recognition provides advantage to customize each individual layer and thus efficiently apply the technology to various scenes.

The technology is effective for judging the work contents at factories.

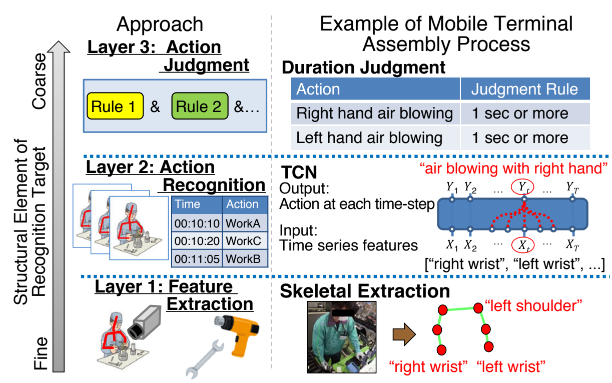

Figure 6. Action Judgment Approach

(2) 3D-LiDAR Sensing

One of the "labor productivity" measures in the construction field is safety monitoring of sites. Among the on-site issues is achieving high-performance monitoring in operating environments such as at night, in a wide area, and sites with many blind spots. To solve this issue, OKI is developing a 3D-LiDAR sensing technology that uses a laser to measure distances in multiple directions from the sensor, acquire the surrounding 3D point cloud data, and detect people and vehicles.

A fast and highly accurate object detection/tracking technology that can be performed on OKI's AI edge computer "AE2100" has been realized, and a wide area monitoring technology is being developed using more than one 3D-LiDAR sensors (**Figure 7**). One feature is the integration of objects detected and transmitted to the host computer from each AE2100. Forming a composite from the transmitted point cloud objects enables a more advanced analysis such as for shape identification of heavy machinery.

OKI's technology is effective for wide area safety monitoring of construction site objects.

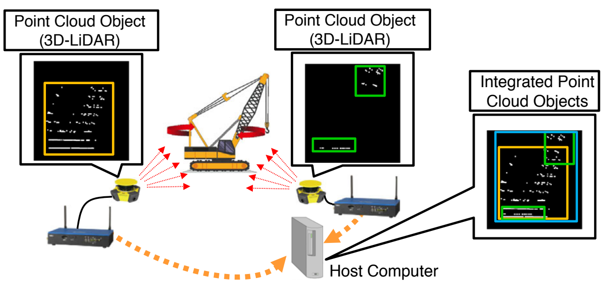

Figure 7. Integration of Distributed Point Cloud Processing on Edge Computer

Highly Reliable Fusion Sensing

In addition to the above-mentioned optical and image technologies, OKI is making advancements in "acoustic sensing[6)]" and "radio sensing" technologies. OKI has a long history working with acoustics in the telegraph and telephone business, and radio in the wireless communication business, and these strengths are now being applied to the sensing area. The company is also aiming to fuse together various sensors according to application as well as fusing signal processing and machine learning.

(1) Acoustic Sensing

Remote communication is being promoted as measure against "infectious diseases" in the field of remote work/ education. Here, issues of ambient noise such as family voices during work from home and the risk of confidential information leakage during office web conferences are surfacing. To solve these issues and improve the remote communication environment, an acoustic sensing technology that enables mics to capture only the target sound and eliminate unwanted noise is under development.

The technology is being used in the development of the area sound enhancement mic that picks up only the sound from a specific area. Two mic arrays are installed so that the overlap of their directivities forms the specific area where the target sound is to be picked up. Utilizing the fact that the target sound from the overlapped area will be picked up by the two mic arrays at the same time and volume, only the target sound can be extracted (**Figure 8**). This solves the problem of picking up noise coming from the same direction as the target sound that is experienced with a conventional mic array.

The technology is effective in removing ambient noise when working from home.

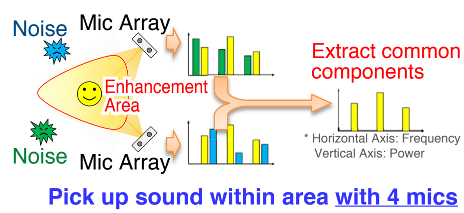

Figure 8. Overview of Area Sound Enhancement

Conclusion

This article introduced OKI's initiatives in the sensing domain to strengthen the "AI edge," and also described the features and application examples of each technology. While focusing on co-creation with customers, OKI will continue its drive forward in creating practical and differentiating technologies that solve on-site issues. ◆◆

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TIPS

【Glossary】

SPR (Surface Plasmon Resonance)
A method in which the sensor chip is irradiated with light while changing the incident angle. The change in the refractive index on the chip is detected as the change in the angle at which the intensity of the reflected light is minimized.