論　文　の　要　旨

題　目　　A Study on HFR-Video-Based Software Sensor for Dynamic Scene Analysis
（動的シーン解析のための HFR ビデオベースドソフトウェアセンサの研究）

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Dynamic characteristics such as velocity, displacement and strain can effectively indicate working conditions of machines in and stability of engineering structures such as bridges and buildings. Dynamic analysis plays an important role in structure health monitoring, fault detection and service life prediction that can greatly reduce maintenance costs and improve production efficiency.

Current methods for dynamic measurement can be mainly divided into two categories by their installation requirements: contact-sensor-based and non-contact-sensor-based approaches. Contact-sensor-based methods, such as strain gauges, velometers, and accelerometers, are directly installed on objects to be observed. These contact-type sensors can provide accurate and robust dynamic signals; however, their installation is generally time-consuming, and their maintenance costs are high. Non-contact-sensor-based methods are mainly based on optical sensors such as Laser Doppler vibrometers, and Vision-based cameras. Laser Doppler vibrometers are highly accurate and sensitive for repeatable measurements in the frequency range of 0-300 kHz. However, they are easily affected by speckle noise and involve cumbersome intermittent measurements. Vision-based solutions are popular for vibration measurements because of their easy installation and non-contact monitoring. However, they require considerable memory for data storage and time-intensive data processing. Moreover, their frame rates are often limited to tens of frames per second, and most of them provide dynamic measurement in a low frequency range within tens of hertz.

To realize higher-frequency-range measurement, high-speed vision systems have been developed to measure dynamic signals in a high frequency range. Compared with standard video formats at low frame rates, high-speed vision systems can execute video processing for HFR images at a high frame rate of hundreds or thousands of frames per second, enabling dynamic measurements at a frequency of 500 Hz or higher. However, captured high-frame-rate (HFR) videos can only be displayed in slow motion to operators on an offline computer display; thus there is a demand for further real-time processing and visualization of high-speed information for more intuitive and widely applications.

To address this point, in this study, I propose a novel concept called HFR-video-based software sensor that combines high-speed digital image correlation (DIC) with real-time dynamic analysis to analyze high-speed and micro movements happening at dozens or hundreds of Hz that cannot be directly seen by the human eye. For high-speed sensing, I develop a GPU-based batch-DIC algorithm that parallelizes a batch of DIC calculation by the strong GPU platform to estimate velocity values of multiple regions simultaneously in milliseconds. Based on high-speed sensing, I develop three kinds of high-speed-vision-based software sensors by real-time dynamic analysis of the velocity signals, namely, frequency-analysis-based vibration visualization sensor, angle-similarity-analysis-based rotation sensor and tapping-analysis-based finger tapping sensor.