Where Theory meets Practice

How Motion Magnification Can Be Used In A Condition-Based Monitoring System

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ABSTRACT:

Motion Magnification Video (MMV) systems can be used as vehicles for condition-based monitoring platforms for high-value plant machinery and equipment. High-speed cameras can be installed permanently or semi-permanently on site, to provide 24/7, remote access while monitoring equipment and measuring vibration frequencies, along with other metrics. A customizable software application can serve as a control center where all target data and metrics can be accessed, Motion Magnification videos can be displayed, and special features, such as alarm triggers, can be set up to accommodate specific needs. The always-on, remote access to this CBM system, and its coverage of the entire machinery space, could reduce the need for manual, on-site equipment checks, cutting down on maintenance costs while improving the visibility and therefore reliability of high-value, vital machinery and equipment. The future of application of vision-based technologies powered by AI is sure to push the boundaries and further the capabilities of these systems.

Keywords: AI, artificial intelligence, CBM, Condition-based monitoring, high-speed video, machinery diagnostics, machine-vision, machinery health, maintenance, MMV, Motion-Magnification, reliability, remote-access monitoring, vibration analysis, vibration detection, vibration video amplification

INTRODUCTION:

Motion Magnification Video is a technique first explored by researchers at Massachusetts Institute of Technology as published in 2005 by which pixel-level analysis is used to smoothly magnify motion that viewers naturally cannot see in videos. The technique has been improved and iterated upon for years and has been used to visually enhance subtle changes in motion and/or color intensity detected at the pixel, and even sub-pixel, level within videos. Also known as video magnification or vibration video amplification, the technique has been applied to various biological applications, from detecting a sleeping baby's breathing to identifying the pulse signal and measuring the heart rate of an adult using a video of their face or hand. In the context of machinery health and diagnostics, MMV has been used to detect the vibrations of running machinery and ancillary equipment, and is a key component of several comprehensive commercial systems available on the market.

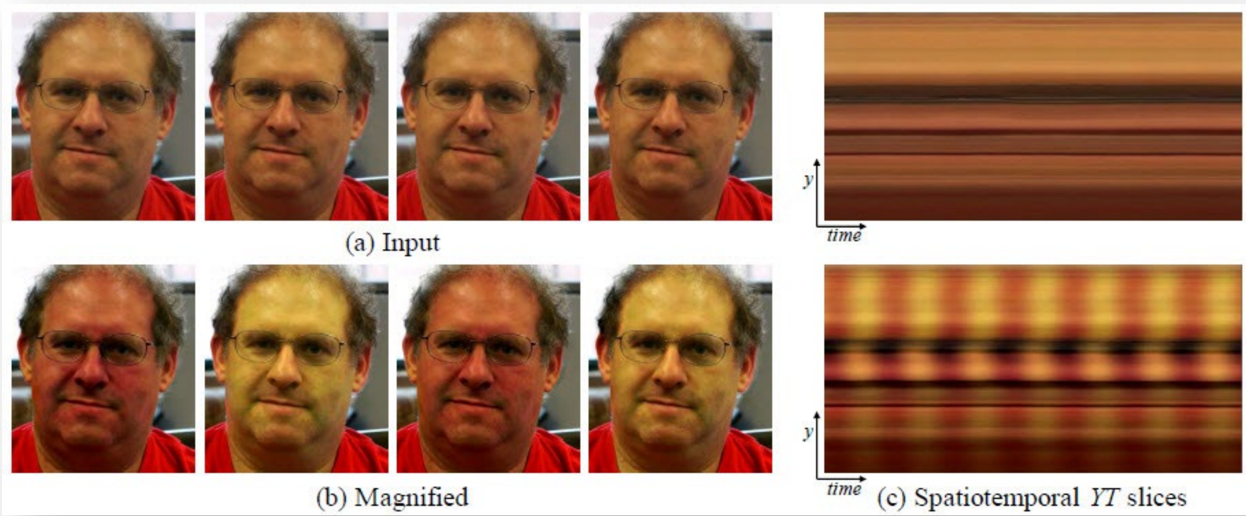

Figure 1: MIT Video Magnification (ref. Liu, C. et al)

As MMV systems have continued to develop over the years, so too have they continued to expand in terms of capabilities, feature-sets, user-adoption, and effectiveness for a wide variety of applications and industries. MMV systems are now a vital tool for many reliability and maintenance departments across a vast range of industries, predominantly within the energy (power generation, nuclear power plants), oil & gas refineries, water and waste water treatment facilities, mining, manufacturing, aerospace & defense, and laboratory testing/research and development. Modern MMV systems, which are usually comprised of several essential hardware components, such as high-speed cameras equipped with lenses and proper lighting, combine these with smart software applications to allow users to capture, analyze, and extract motion metrics detected by the camera. Modern systems are not only capable of detecting subtle vibrations of equipment and creating MMVs that visually represent the vibration modes or patterns, but can provide precise measurements of the data as well. Through years of developmental testing and tweaking calibration parameters, these software applications have been fine-tuned to produce measurements with precise accuracy, improved MMV clarity, improved user-friendliness, and expanded features and functionality. Today, MMV systems have great potential to become a widely adopted tool able to be installed as part of a condition-based monitoring platform to further increase visibility and reliability of equipment, even when a user is not present.

By using each pixel of a camera as a sensor, many thousands of individual data points are collected and therefore, thousands of locations in scene can be monitored simultaneously. MMV systems can observe the driven and driver machinery as well as piping and the entire machinery space, without the need to manually probe countless individual areas of the equipment with accelerometers. Users can save money on sensors, wiring, maintenance, walkaround monitoring, etc.

KEY COMPONENTS OF AN MMV-CBM SYSTEM

As a comprehensive tool for diagnostics and equipment monitoring, MMV systems are comprised of several key components to ensure the highest quality video is captured in order to achieve the best performance and results of the system. From a hardware perspective, the cornerstone of any MMV system is the camera, which in best practice would be high-speed and high-resolution. Camera selection is a crucial component, along with other factors such as lenses and lighting, in that these determine the quality of the video image and raw pixel data captured during recording. This raw data is used when applying embedded advanced mathematical algorithms, along with some user-defined inputs, to produce the resulting MMVs and measurements for displacement, velocity, and acceleration along a frequency spectrum, among other metrics and features. The camera's recording speed, along with throughput bandwidth, determines the resolution and frequency detection range of an MMV project.

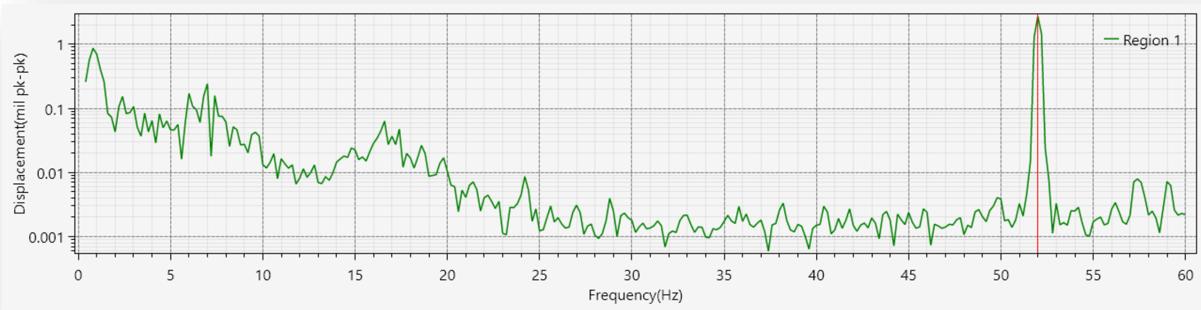

Figure 2 - FFT plot of displacement over frequency span

Other hardware components, such as lenses, lighting, and structural supports (tripods with vibration reduction pads installed), also play a role in the quality of the video captured with an MMV system. Knowing good practice techniques for setup and preparation for recording a high-quality video for MMV systems is imperative to avoid unexpected issues that could occur in post-processing. With existing mobile MMV systems, users can deploy their mobile MMV kit at various different locations within a facility, take a short 5-10 second video, and then move to the next machine or piece of equipment. However, MMV software applications have advanced to the point where hardware can be permanently or semi-permanently installed within a facility to monitor high-value, vital machinery and equipment.

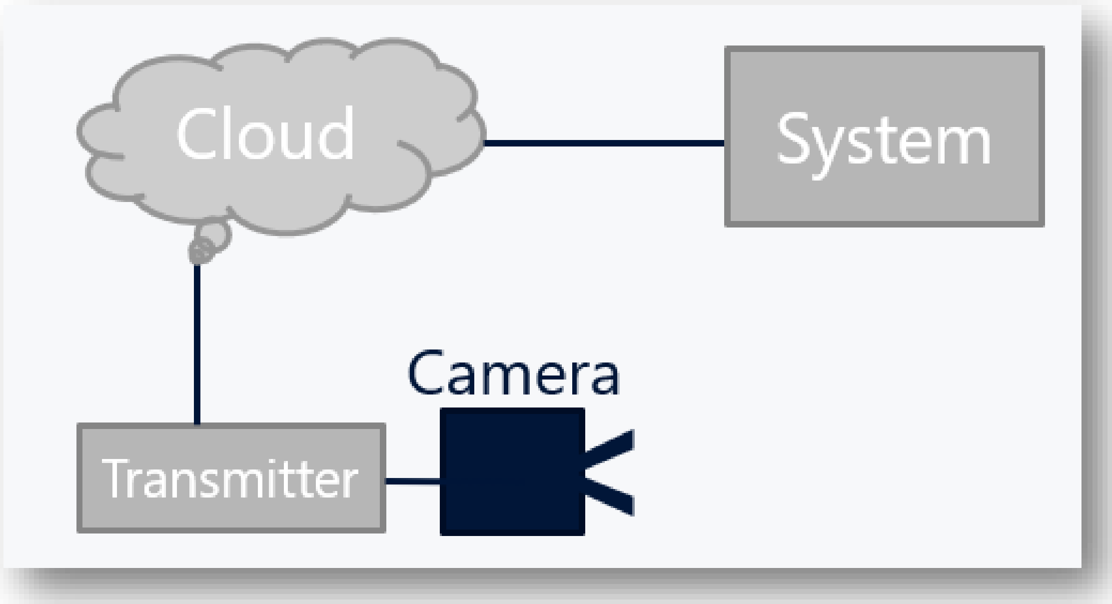

Figure 3 - Basic MMV-CBM configuration

The software application used to capture, process, and analyze video data to create MMVs can be configured with customizable options and features tailored to the needs of each individual facility, machine or piece of equipment. Also, these systems can be configured to relay video data to the cloud, where MMVs, measurement data and other information can be accessed remotely over a network connection. Live, 24/7 monitoring of equipment is now accessible with the installation of video cameras that stream their data to the image processing applications on a remote system.

CUSTOMIZABLE & CONFIGURABLE SOFTWARE APPLICATIONS

The possibilities/options for customizing a MMV condition-based monitoring system on the software level are virtually endless. Given the proper expertise and knowledge about how a particular machine or piece of equipment behaves, users can configure an MMV-CBM system to recognize when a machine or piece of equipment is not behaving as it should. For instance, when something out of the ordinary is detected by the system, “alarm triggers” can be activated upon detection of abnormal vibration levels in terms of frequencies, displacements, velocities, and accelerations. Once these detection thresholds have been triggered, an alarm notification can be sent to notify the equipment operations and maintenance managers responsible for keeping operations online.

Once notified, these users can then access their “control center” interface in the application remotely over a network connection, where they can further assess the events occurring within the video feed. From this control center, users can see the issues that have been detected and view live measurement readouts. They can even access MMVs created by the system that help visualize the movement occurring within the scene. With access to a live view of their equipment and precise vibration measurements, reliability managers can make informed decisions about the nature of the issues and whether or not urgency is required to deploy immediate attention from technicians and troubleshooting teams.

Another configurable option for a live MMV-CBM system is to set up event/cycle detection routines or history logs. With the system configured properly, it is able to log machine operation duration, offline-to-running cycles, and event detection of certain expected or unexpected events that happen within a scene over a period of time. Additionally, machinery issues, incidents, and regular maintenance or checkup/assessment periods can be tracked to create a full timeline of a machine's life, similar to a person's full medical record. These logs can provide users a comprehensive view of their machinery operational life-span to help inform decisions about maintenance, troubleshooting issues, and potentially taking the machine out of operation. This can provide additional insights in the history of a machine to help troubleshooters, operations, and maintenance reliability personnel make decisions in the event of recurring issues that may warrant extra attention in providing a solution. This historical timeline of a machine's lifespan can be stored along with MMVs and measurement data taken from the machine at each stage of its life and kept for future reference.

BENEFITS OF INSTALLING A REMOTELY-ACCESSED PERMANENT OR SEMI-PERMANENT MMV-CBM SYSTEM

There are several important benefits to installing a permanent or semi-permanent MMV-CBM system. Fundamentally, it automates a lot of the manual labor typically required to check in on equipment and saves a lot of time and money in the process. Not only this, but the 24/7 live monitoring component substantially increases the visibility and reliability of a machine over its lifespan. Without the need of requiring an employee to perform physically-intensive check-ins periodically on equipment, users can monitor their systems remotely from the comfort of an office or at home.

With the flexibility of fully customizable options and functionality, users can build smart features into the system developed using much of the domain expertise required to properly perform machinery diagnostics and troubleshooting. This automation and fluidity of data increases the visibility with trained vibration and reliability experts internal to the plant, without which could require the consulting of outside help for expert opinion to make an informed call when dealing with issues of high-value machines.

A software platform that uses MMVs, tracks measurement data, and logs the history of the lifespan of a machine, gives users a fully comprehensive view of their equipment that can be accessed anywhere, at any time.

Machine-vision and automation is a growing industry and as the technology continues to improve, it is being used in more applications and industries every year. This domain is sure to continue to become more widely adopted and garner attention from developers, technical personnel, and manufacturing OEMs alike, leading to improvements across the technology stack and further continuing the cycle of investment and development among industry trailblazers.

THE FUTURE OF SMART, VISION-BASED MONITORING SYSTEMS

As mentioned in the section above, machine-vision based technologies are here to stay as they are continually being improved and deployed for many applications in today's society. Self-driving cars, drones and UAVs, and high-end surveillance technologies continue to push us forward into new frontiers, and so too will these advancements and breakthroughs trickle down to more everyday applications across industries. Robust systems powered by AI are using video-based data and images, enhanced through massive AI training endeavors to be more effective, efficient, and accurate when called upon for today's defense and commercial applications alike. AI-powered features and agents are likely to pervade systems used across all industries in the coming years. Also, we should continue to see improvements to camera hardware and sensor technology, further improving upon the base level of performance we have achieved with today's commercial off-the-shelf machine vision cameras.

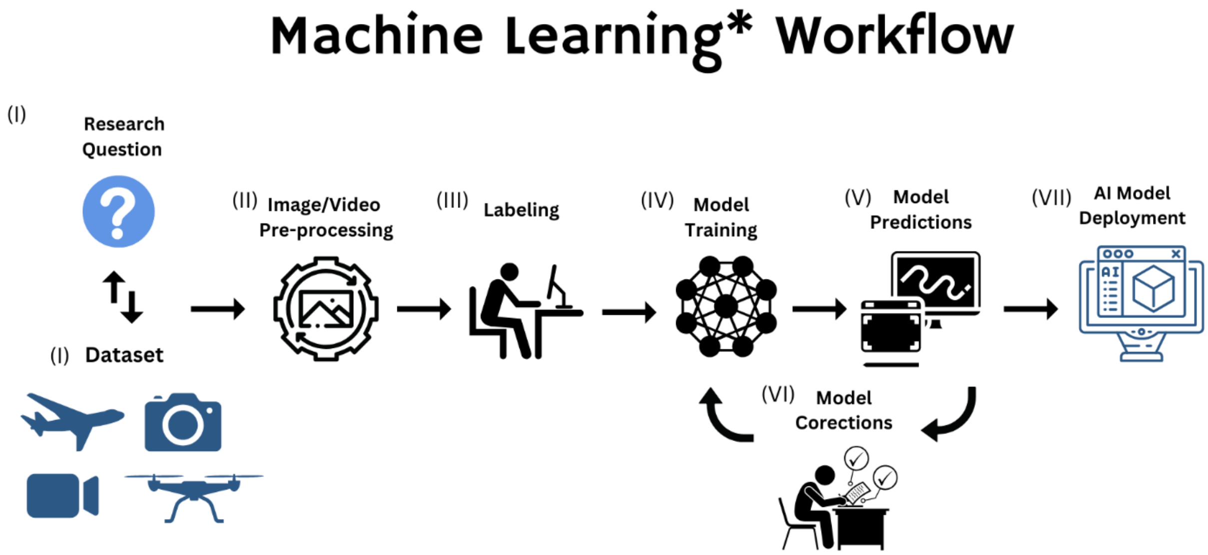

Figure 4 - Schematic of workflow utilizing computer vision AI training model. (ref. Sorrentino, C.)

With AI-enhanced video processing, MMV software applications will become more accurate and efficient for detecting issues, recognizing root causes, and taking the next steps through inference and execution. Smarter and more effective event detection will be able to provide summaries and descriptions of issues, along with potential solutions to the issues being experienced. The autonomous nature of MMV-CBM systems will likely require even fewer manual inputs and human intervention as the process of detecting issues and deploying solutions can become even more streamlined in the future. Using AI data analytics, we will better understand the behaviors of machinery to anticipate issues and increase failure prevention using predictive diagnostics and forecasting. The implementation of MMV-CBM systems powered by AI is likely to further reduce the risk for equipment and machinery failure and prevent catastrophic issues.

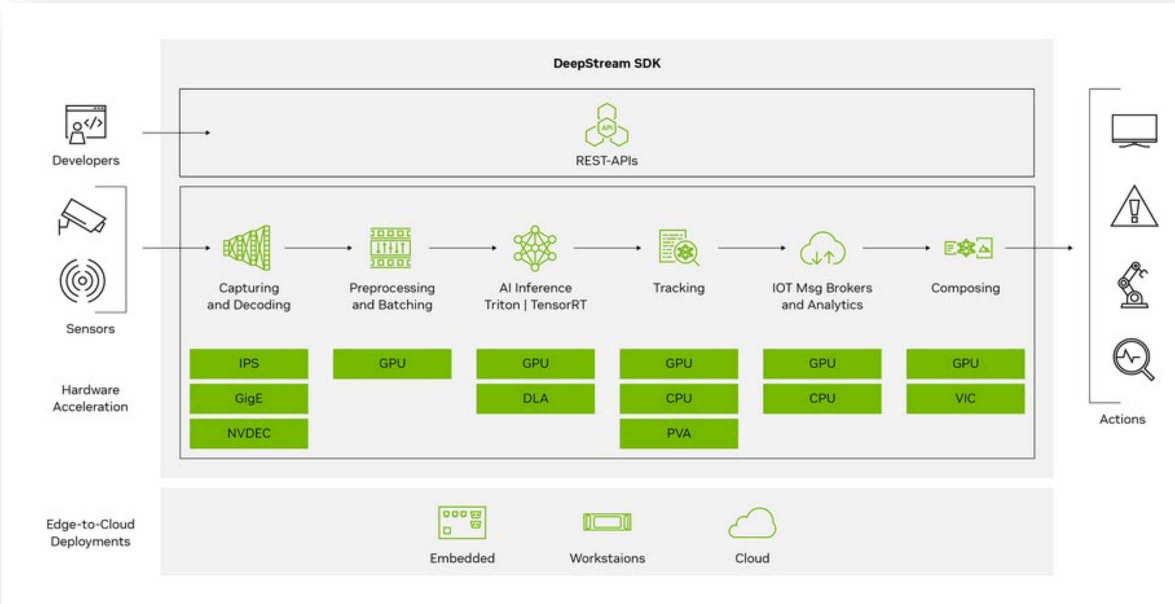

Figure 4 - Model of Nvidia's DeepStream SDK

CONCLUSIONS:

MMV systems are capable of being built into CBM platforms across industries today. Using camera pixels as sensors opens the door to countless possibilities when processing the images with Motion Magnification and vibration analysis software. MMV and vibration analysis software applications have enabled live measurements and analysis workflows to be accessed remotely over a network. Smart, configurable software options give users the ability to monitor and safeguard high-value machines and equipment effectively and with a peace of mind which they never had before. 24/7 remote access to live views of machines exponentially increases visibility of them, and drastically increases the chance of potential malfunctions or failures to be detected early and prevented. AI-powered image-processing applications are here today and will make their way to MMV and vibration analysis software soon. AI will further bolster and supercharge the capabilities of the MMV-CBM systems of the future.

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