An Online System for Remote SHM Operation with Content Adaptive Signal Compression

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ABSTRACT

Remote engineering systems are valuable tools to give visual assistance and remote support e.g. in NDT (Non-destructive Testing) or SHM (Structural Health Monitoring). They allow discussing a second opinion with a remote expert and thus reducing the human factor during testing and monitoring. For an optimal impression of the situation, the second person requires both a camera view of the location and the screen view of the system used. The OMA system (Online Maintenance Assistance) implements this two-view collaboration. Remote partners can see and actively control the equipment, while observing details of the location in the camera window. Due to varying working conditions, screen signals and communication properties, an adaptive compression for both signals (camera and screen) is proposed. This permits to always maintain the best possible visual quality for the assessment performed by the remote partner.

KEYWORDS : *Remote Maintenance, Teleconferencing, Remote Monitoring, Non Destructive testing (NDT), Structural Health Monitoring (SHM).*

INTRODUCTION

To illustrate the usage of the OMA system for Remote SHM, an example illustrated in fig. 1 is used. On the left side, a 15 m² aircraft door segment with a PZT based active sensor network is shown. By analyzing Guided Ultrasonic Wave propagation e.g. using FFT and wave velocity analysis the System Under Test is analyzed under different conditions. The PZT network is controlled by an SHM Diagnostic Unit (Acellent ScanGenie) and a SMART (Stanford Multi-Actuator-Receiver Transduction) composite software, which can give detailed information about material property changes as described in [1, 2]. An OMA remote conference is established to the remote expert on the right side. A two channel transmission displays both a video camera window and a software window with the PZT network control software. This allows the remote expert to observe the structure and the sensor installation while controlling the software of the diagnostic unit. The latency difference between both views is minimized to always make sure, that the camera view and the current equipment display correspond to each other.

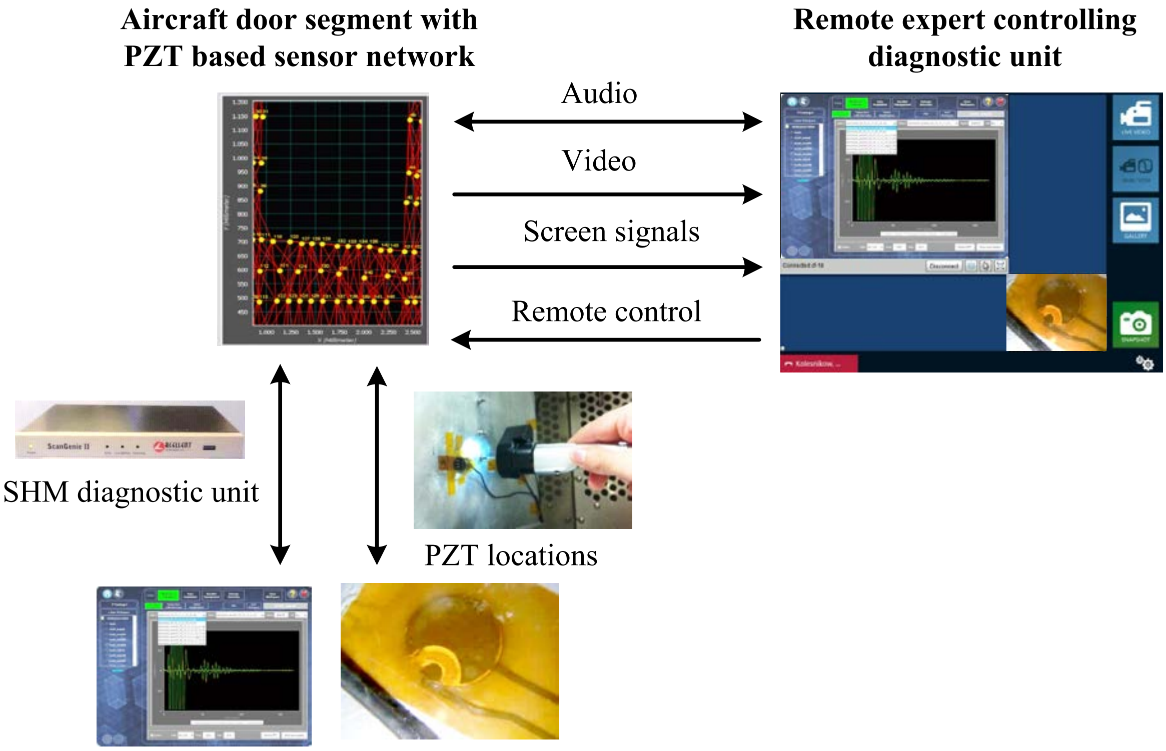

Figure 1: Using the OMA system for Remote SHM

1 RELATED WORK

A commercial off the shelf system for the remote control of desktop PCs is WebEx [2]. It is often used for screen sharing e.g. for discussing documents during web conferences. There is an integrated audio conference (consuming about 20 kBit/s) and the view can be changed to a full-screen video window with limited resolution. It will be used as a reference in the following chapters.

Specialized mobile systems for industrial video communication on dedicated hardware are available, but difficult to integrate with test equipment or measuring systems [3, 4]. Due to existing limitations, an Online Maintenance Assistance (OMA) system for Commercial-Off-The-Shelf (COTS) Laptops was developed as described in [5, 6]. Several integration steps were performed with NDT equipment [7, 8, 9, 10]. Due to the increasing importance of SHM concepts and systems in aircraft development and testing, OMA integration was enhanced to support SHM systems like PZT based active sensor networks [11]. During operation, the secure cross-company network communication has shown to be an important bottleneck. For speech communication a separate telephone server calls the conference participants. This way, the full bandwidth of the communication channel is available for video and screen signals. OMA operates using secured connections over public mobile communication networks. The limited uplink makes an efficient and adaptive compression of all relevant signals transported to the remote side necessary [12].

2 ONLINE MAINTENANCE ASSISTANCE USED FOR REMOTE SHM

The OMA system operates in web browsers on Windows, Linux and MacOS PCs, laptops and tablets. An installation is only required on the remotely controlled computer. OMA can use existing cameras, brings an own macro camera and can use the video signals from external video sources like microscopes, borescopes etc.

The integration with an NDT or SHM system is shown in fig. 2.

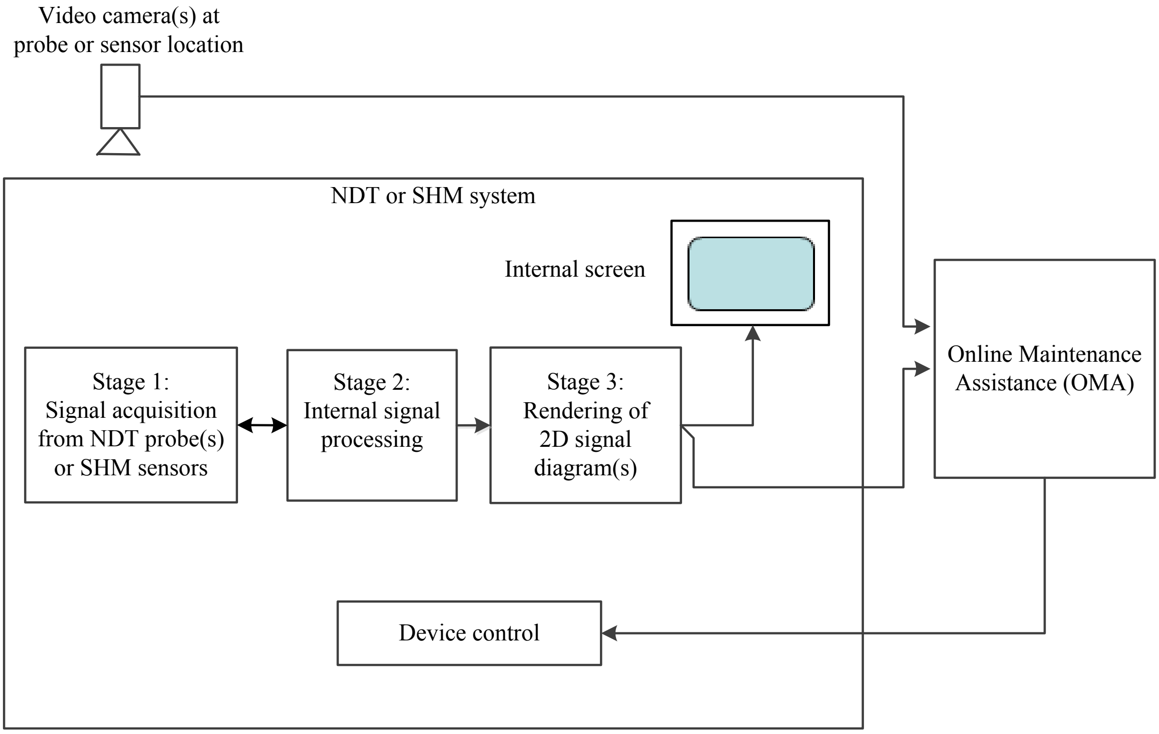

Figure 2: OMA integration with NDT and SHM systems

The signals are acquired from sensors or probes in stage 1. Internal signal processing takes place in stage 2. Next, the diagrams are rendered for displaying them on the internal screen in stage 3. OMA uses the screen signals and performs an adaptive compression on them. The following table shows different measurement principles chosen according to their relevance at Airbus and Testia maintenance sites. For a correct remote assessment, the screen update rate (in frames per second – fps) required for a sufficient visual quality is crucial as described in table 1:

Table 1: Frame rate requirements for different types of SHM/NDT measurements

Measurement principle (Device manufacturer)	**Required screen update rate (fps)**
PZT based SHM system (Acellent)	1-2
Ultrasonic A scan (Testia, NDT Expert, Olympus)	10-15
Ultrasonic C scan (see above)	1
Eddy current (Rohmann, GE Krautkremer)	20
Borescopes (GE)	15

It is visible, that the SHM system and one of the four NDT systems can operate at slow screen update rates. Ultrasonic A scans, eddy current measurements and signals from borescopes show a very dynamic signal behavior requiring a fast update rate to reach a sufficient visual quality.

3 COMPARISON OF SCREEN COMPRESSION CODECS (COMPRESSORS/DECOMPRESSORS)

Portable computers at remote maintenance sites often use public mobile networks based on EDGE, UMTS, HSPA or LTE. There are two reasons for this:

1. The remote expert cannot be reached inside the company intranet (other organization).
2. Network access is not available at all locations of maintenance or testing sites.

The OMA system uses secured communication with AES-256 encryption to ensure, that safety regulations as applicable in the aeronautics industry are met. Usually, the upload channel is the limiting factor, since screen and video signals need to be sent to the remote expert. In table 2, typical realistic upload bandwidths in mobile communication networks are described with coverage information in Europe [13, 14, 15, 16]:

Table 2: Typical available upload rates in different mobile communication networks

Mobile communication network	Typical bandwidth	Population coverage France	Population coverage Germany	Population coverage EU 27
EDGE	80~100 kBit/s	~ 99%	~ 99%	n/a
UMTS	300 kBit/s	92	86	90
HSPA	1 MBit/s	99,7	90,4	96,3
LTE	3 Mbit/s	5,5	51,7	27,0

HSPA and LTE coverage is typically limited to larger cities and big airports. Thus it is necessary to implement high video and screen compression. The most important component affecting the visual quality is the codec (compressor/decompressor). For the OMA video channel, H.264/AVC is used. The remote viewing/control channel uses a JPG based screen codec. The first comparison will shows screen compression quality of OMA and WebEx [2].

3.1 Comparison between OMA compression and WebEx compression

To allow for an accurate comparison, the quantization level of the OMA JPG compression is compared to the WebEx compression at three levels as shown in figure 3.

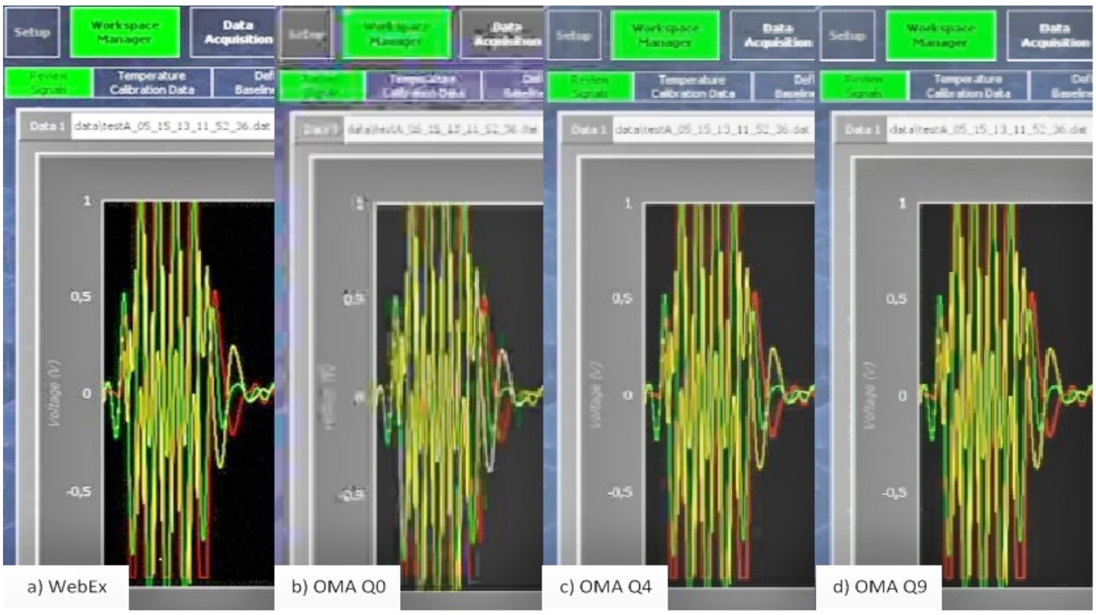

Figure 3: Comparison of WebEx and OMA screen codec with quantization levels Q0, Q4 and Q9

It is visible, that a quantization level of 4 is the lower limit for correct assessment. In table 3, the achievable frame rate of the OMA (at Q4) and the WebEx screen codec are analyzed and compared to the requirements from table 1.

Table 3: Frame rate requirements compared to OMA and WebEx performance.

Measurement principle	Required update rate (fps)	WebEx update rate (fps)	OMA update rate (fps)
PZT based SHM system	1-2	0.5	0.6
Ultrasonic A scan	10	0.8	3.0
Ultrasonic C scan	1	0.8	3.0
Eddy current	20	1.48	2.8
Borescope	15	1.4	2.0

For the SHM system both codecs deliver a slow frame rate. For NDT systems the OMA codec is between 1,5 and 3,8 times faster (more dynamic) than the WebEx codec. For ultrasonic A scans, eddy current measurements and borescopes the WebEx is very slow making it difficult to achieve an accurate remote impression of the signal.

3.2 Comparison of bandwidth requirements for OMA and WebEx screen compression

The next diagram shows the average bandwidth of the screen codecs for different signals:

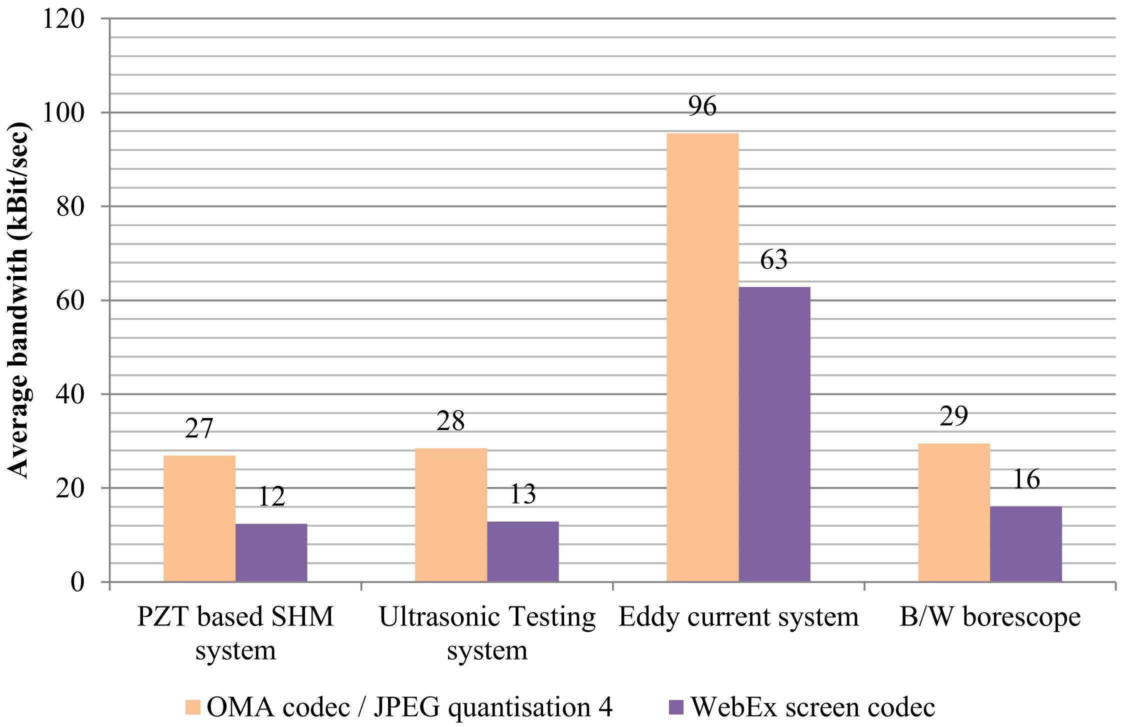

Figure 4: Bandwidth (kBit/s) OMA screen codec vs. WebEx screen codec

The ultrasonic system was used with both A and C scans visible in different windows. OMA compression requires more bandwidth than the WebEx compression. The reason is the limited frame rate of WebEx, which is insufficient for dynamic screen signals.

All bandwidth results in fig. 4 remain within the limits of the slowest mobile communication network (EDGE) in table 2. In three out of four cases the remaining bandwidth allows for a second parallel video channel, which typically requires ¼ of the bandwidth at a window ratio described in fig. 1:

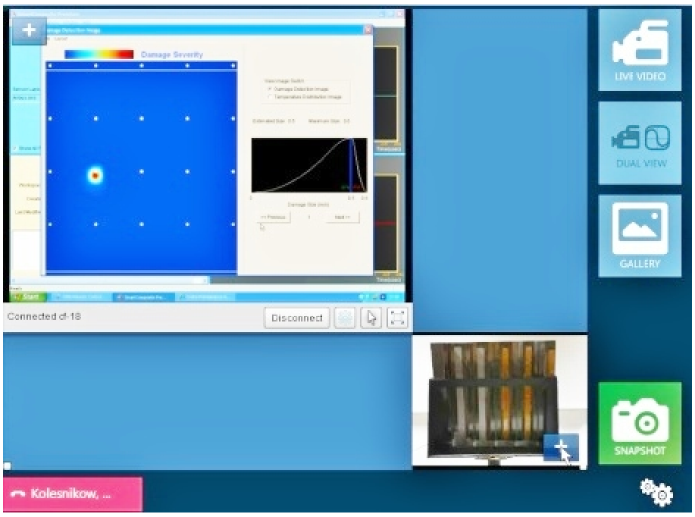

Figure 5: OMA user interface at a screen/video ratio of 1:3

If the camera window and/or the control buttons are not required, the screen window (top left) can be switched to full screen.

3.3 Comparison of codec performance and bandwidth requirements for a OMA and H.264 screen compression

Though the OMA JPEG screen codec is suitable for many signals, a more dynamic screen codec would allow for better dynamics esp. at fast signals requiring 10 ~20 fps frame rate. To achieve this, adding a second video channel using H.264 compression in addition to the existing OMA codec by is analyzed. To reach a sufficient level of the visual quality video codec parameters are adapted.

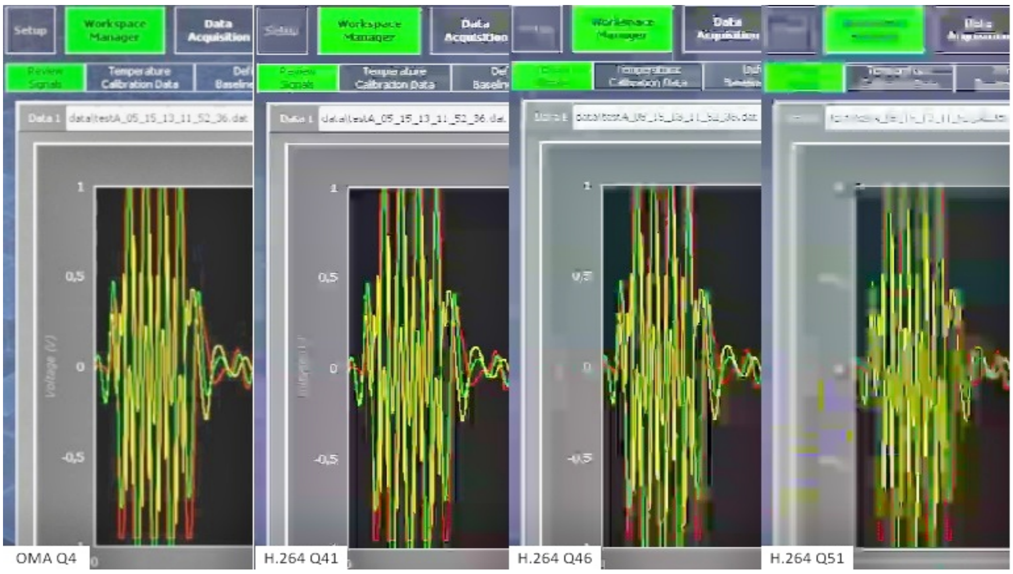

Figure 6: Comparison of OMA screen codec with quantization level 4 and H.264 with q. levels of 41, 46 51

The required bandwidth range for H.264 quant. level 41 is 317-1351 kBit/s compared to 248-773 kBit/s at quant. level 51. Considering table 2 it is obvious, that in most european locations the additional bandwidth required by the video codec is available and OMA conferences allow sufficient screen update rate for dynamic screen signals.

4 CLASSIFICATION AND AUTOMATED CHOICE OF OPTIMAL COMPRESSION FOR DIFFERENT SCREEN SIGNALS

To always achieve the best visual quality parameter and codec profiles for all relevant SHM and NDT systems and the mobile networks in table 2 were generated. They can be switched by the SHM/NDT operator during the OMA conference. In the future, an adaptive approach will be used which is currently under development. It is based on a classifier which operates according to the strategy described in fig. 8.

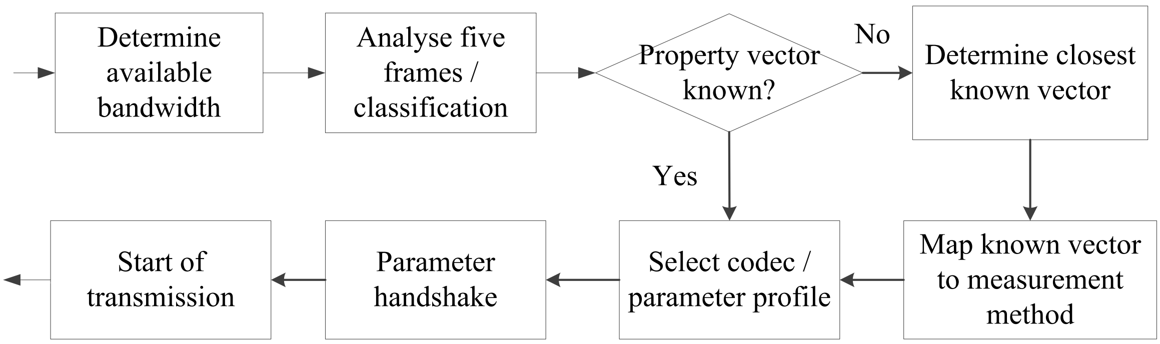

Figure 8: Classification of screen signals for automatic codec selection and adaptation of compression parameters

When starting a screen transmission, the available network bandwidth is detected first. Then, the first five frames are analyzed using a property vector containing signal dynamics, color spectrum and color depth. If the property vector is not similar to existing signal vectors, the closest vector is chosen and the associated measurement device is chosen. The codec (as described in chapter 3) is selected and compression parameters like frame rate and quantization are optimized. The parameters are sent to the partners OMA system and the transmission can begin.

SUMMARY AND OUTLOOK

It was shown, that OMA screen compression outperformes WebEx by a factor of 3.8 for dynamic signals like in most of NDT applications. Slower NDT and SHM applications benefit from a smoother and more realistic handling of the controlled software. Additional increase of the screen update rate will improve visual quality for dynamic signals like ultrasonic and eddy current measurements. Currently compression profiles are switched manually, but a classificator will soon allow automatic adaptation. Since most of the OMA system is browser based, it can be used on laptops or tablets and will be available for the iOS based iPad soon.

The compression benefits can be used for sensor data compression and direct sensor data communication as well. New OMA integrations with several devices from Testia partners are ongoing. This includes new testing technologies, devices and other signal related aspects. In addition, it is analyzed, whether for some systems a full user interface integration is desirable. The authors are interested in other SHM and NDT techniques and applications, where remote cooperation with multiple views and signals are an interesting alternative to the existing ways of collaboration.

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