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REAL-TIME INSPECTION AND MONITORING OF MARINE DIESEL ENGINE MECHANICAL PARTS BY COMPUTER VISION

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ABSTRACT
Marine diesel engines' parts are under various loads, usually time-varying, during their normal operation. This causes complex dynamical state of stress, and can produce unwanted high deformations and degradation of material, give a rise to critical crack growth and, finally, to failure of one or more of the engine parts.. The effect is further emphasized by marine atmosphere. This paper proposes a system for real-time monitoring and inspection of marine engines parts. Wavelets are used for: compression of data, detection of changes in engine condition (difference between referent and current frame) and for removal of vibrations caused by engine (vibrations caused movement of observed points due to motion of camera).
Keywords: computer vision, marine diesel engine, wavelet

1. INTRODUCTION
Computer vision will take more and more important role in engine room aboard future ships. In this paper, a monitoring system is proposed. Problems with marine diesel engines can result in ecological catastrophe [1]. Problem occurring are emphasised in engine room manuals [2], and it is actual in both military and civilian ships. The problem is even included in certification process [3]. A part of software solution for the proposed system is wavelet compensation of the vibrations caused by ship's engines. Because of constant advance in wavelet analysis [4, 5], it was possible to propose such solution for considered monitoring system. Wavelet compensation and compression are performed by 3D discrete wavelet transform (3D DWT) [6 – 8]. As a part of 3D DWT, temporal compression is included [9]. This gives the opportunity to compress data both in space and time. It is possible, because of long time without motion. While literature about wavelets is quite extensive, proposed application is novel.
Diesel engines' parts are under various dynamical loads during normal operation [1, 2, 10]. This cause's complex stress state and can produce degradation of material, cracks formation and consequently engine failure [11]. Ship's engines are often under additional loads due to varying operating and environmental conditions. Loads can cause cracks in affected parts of the engine and produce oil or fuel leak or even greater failures [12,13]. Unexpected failures can lead to wide range of undesirable accidents. We propose computer vision system for real-time inspection of marine engine parts. Stress effects is recorded and analyzed over time to calculate possible risks and preventive replace of exposed parts. Image correlation is used to detect changes between referent image and current frame. Data is compressed to reduce amount which must be compared over time. Compressed sequence contains a record of data obtained during operation and its comparison to the average curve of operation. If there is a deviation greater than previously established threshold, the part of the engine should be replaced. Deviation is expressed by root-mean square error. Threshold can be determined heuristically by experience form practice.
Description of the problem is given in Section 2 and proposed solution is explained in Section 3. In Section 4, some conclusions and guidelines for further research are stated.

2. DESCRIPTION OF THE PROBLEM

During normal operation engine part material can be degraded or damaged due to stress. The results are shown in Figure 1. However, these damages do not appear form nothing. Firstly, small crack is opening. The process starts at atomic level and keep widening until it appears at macroscopic level, visible to human sight. To prevent catastrophic course of events, it is useful to detect crack and potentional damages sooner. That is the reason for introduction of computer vision, as our proposal, to monitoring of engine parts.

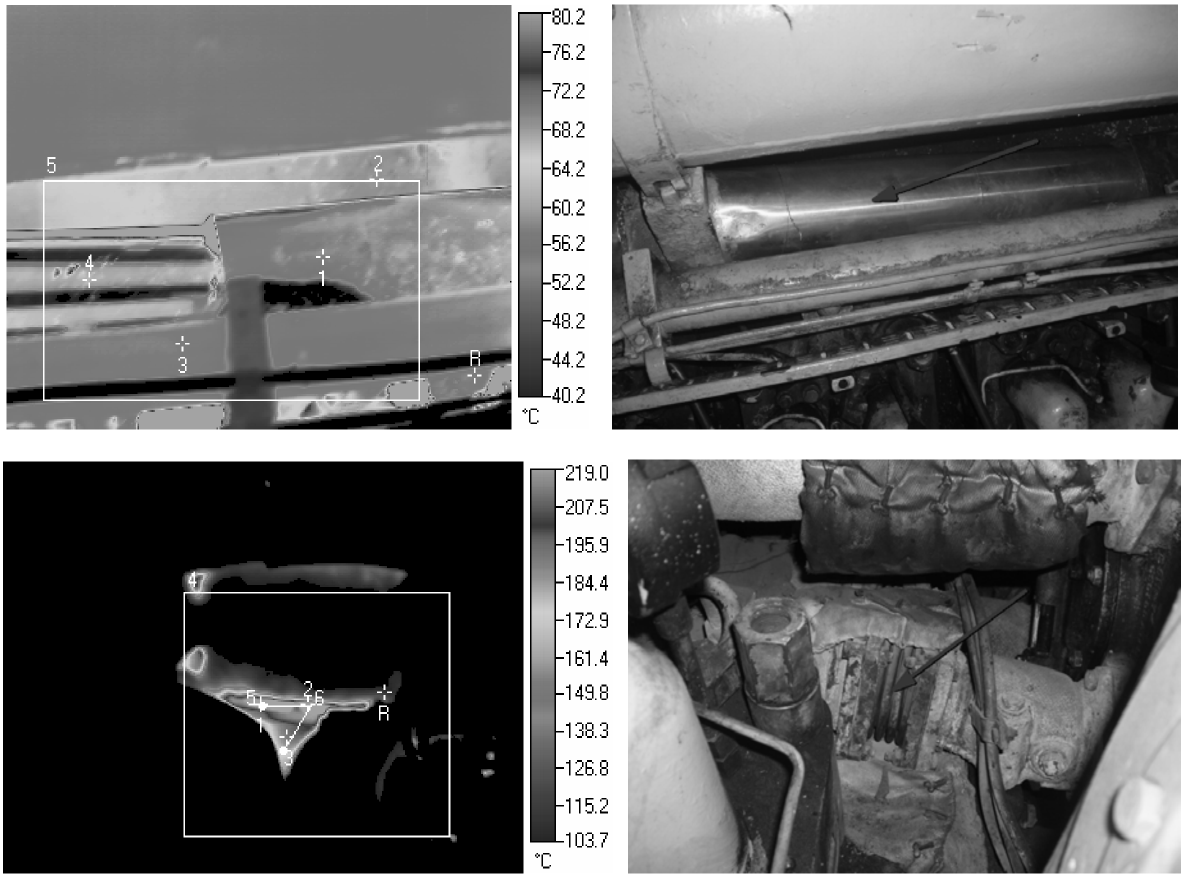

Figure 1. High stresses effects to engine parts form actual ship.

3. COMPUTER VISION SOLUTION

To choose the appropriate camera, we looked for at different manufacturers (i.e. [14 – 16]). Demands to the system are: operating temperature, operating pressure, operating spectra, communication, physical size, resolution, covered angle, etc. It is logical to choose that this temperature is in operating range of the camera. This is limitation factor since most cameras works with upper limit of 60°C [14 – 16]. Most of the cameras work within pressure of the 3 bars, which is adequate for the proposed system. Since there is no need for actual real-time operation (up to 30 frames per second; a few frames per second are adequate), the resolution is not limited by ability of the system to process a large amount of data. So, it is not determining factor. However, it is better to have larger resolution, because the system must be able to detect small cracks and changes in shapes.

The next problem is about communication between image acquisition part and processing/alarming part. Since, it is impractical to use wires, we choose wireless link. Part of the system which displays the crew members the sign of the alarm situation is located in the ship's engine room.

All of the previously mentioned problems in the system design deals with actual hardware problems. But, there are also software problems. There are about wireless communication, coding, noise, reliability of the link, threshold choice in the determination of the motion, data archiving (regulations state that all data must be recorded), etc. Since storage of the continuous video material requires a large storage capacity, it is practical to compress the data. This part is performed by the wavelets.

Since the vibrations of the camera, because of the engines operation, causes virtual motion (parts of the scene are captured at different location of the acquired image), this effect causes false alarms. Therefore it is vitally important to reduce or even eliminate these false alarms. Reduction of such virtual motion should be performed by 2D+T DWT [17, 18].
Figure 2 illustrates „vibration removal" property of 2D+T DWT.

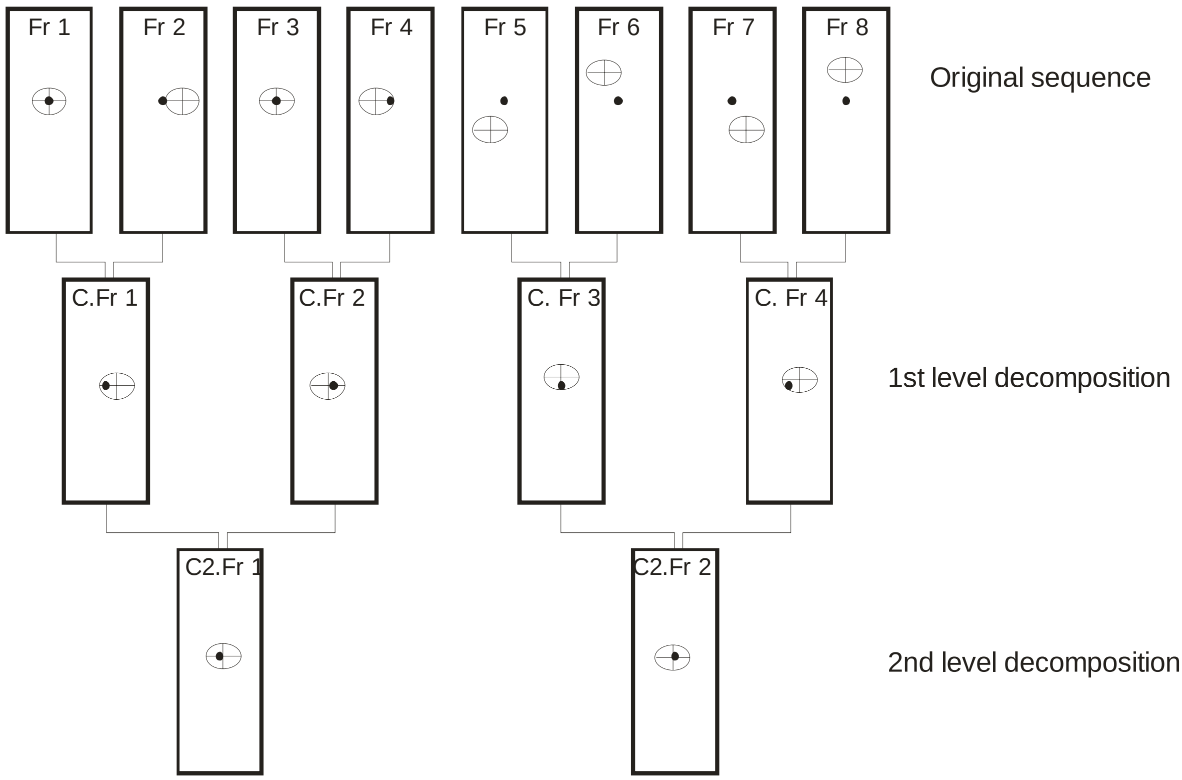

Figure 2. Temporal compression leads to smaller oscillations in spatial localization (courtesy of Igor Vujović [19])

4. RESULTS

Experiments are performed at NEC notebook with mobile AMD Athlon XP-M 2600+ processor working at 1.67 [GHz]. The system has 480 [MB] RAM and the operating system is MS Windows XP with service pack 2. Application for programming and execution was Matlab 7.0, Image processing toolbox, Image Acquisition Toolbox and Wavelet toolbox.
Although the proposed system could not be implemented due to complexity of the proposal (it is necessary to have a real ship and to install the system, to rent the ship for testing, pay expensive experimenting or to find a company which will do it willingly), the proposed visual part of the system is tested in off- and on-line conditions. Test software is implemented in Matlab. Since, it is in test phase, it was important to see whether the algorithm works well. We observed that simulation of vibrations cannot replace a real vibration, because the simulation can give any spatial displacement. So it was not possible to evaluate how much decomposition levels are necessary. So we choose threshold of one pixel displacement.

5. CONCLUSIONS

The main drawbacks of the 3D wavelet transforms include a long-time latency and the inability to adapt to fast motions. However, this is not such a case, so it was possible to adopt 3D (to be precise: 2D+T) DWT. Manifold of the wavelet motion compensation is therefore avoided.
The choice of EM spectra is based on previous research [20], although it is possible to use camera in visual part of EM spectra as well.
The proposed system is not yet tested in real conditions. Further work should include Visual C implementation for development of stand-alone application and testing on the real ships.

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6. REFERENCES

[1] Sayyaadi, H., Hemati, P.: Offshore accidents and effects on their performances, *MTTS/IEEE TECHNO-Ocean* Vol. 1, No 4, 2004, pp. 212 –217,
[2] *: Engineman 1 & C, Nonresident Training Course, USN, 1987,
[3] *: Optimised Environmental Technologies for Cruise and Ferry Vessels, Technical Report, Det Norske Veritas, 2000,
[4] Vujović, I., Kuzmanić, I.: Wavelet Downsampling in Image Compression, 47^{th} International Symposium ELMAR, 2005, Zadar, Croatia, pp. 99-102,
[5] Vujović, I. Kuzmanić, I., Vujović, M., Pavlović, D., Šoda, J.: Wavelet Evolution and Flexible Algorithm for Wavelet Segmentation, Edge Detection and Compression with Example in Medical Imaging”, chapter 13 in the book: Vision Systems – Segmentation & Pattern Recognition, Goro Obinata and Ashish Dutta (ed.), I-Tech Education and Publishing, Vienna, Austria, ISBN 978-3-902613-05-9, 2007, pp. 243-268,
[6] Božinović, N.: Advanced Motion Modeling for 3D Video Coding, Boston University, PhD Thesis, 2006,
[7] Wang, B., Wang, Y., Selesnick, I., Vetro, A.: Video Coding Using 3D Dual-TreeWavelet Transform, EURASIP Journal on Image and Video Processing, Vol. 2007, Article ID 42761,
[8] Brault, P.: On the Performances and Improvements of Motion-Tuned Wavelets for Motion Estimation, WSEAS Transactions on Electronics, Vol. 3, No. 1, 2004, pp. 174-180,
[9] Mehrseresht, N., Taubman, D.: An Efficient Content-Adaptive Motion-Compensated 3-D DWT With Enhanced Spatial and Temporal Scalability, IEEE Transactions on Image Processing, Vol. 15, No. 6, 2006, pp. 1397-1412,
[10] *: “IEEE Recommended Practice for Electrical Installations on Shipboard IEEE Std 45-2002 (Revision of IEEE Std 45-1998)”, 2002,
[11] Collins, J.A.: Failure of Materials in Mechanical Design, John Wiley & Sons, New York, 1991.,
[12] Letova, T.I., Petinov, S.V.: On the Initial Phase of Fatigue Failure of Structural Elements, Problemy Mashinostroeniya i Nadeznosti Mashin, No. 5, 1992.,
[13] Xiros, N: Robust Control of Diesel Ship Propulsion, DNAME, Technical University of Athens, 2003.,
[14] Cyberia Corporation, on-line: http://www.cyberia-company.fr/,
[15] Imaging Corporation, on-line: http://www.imaging1.com/,
[16] CCTV gadgets, on-line: http://www.cctvgadgets.com,
[17] Polytechnic University of Brooklyn – Wavelet Software, on line: http://taco.poly.edu/WaveletSoftware/ standard3D.html,
[18] Jin, F., Fieguth, P., Wigner, L. : Wavelet Video Denoising with Regularized Multiresolution Motion Estimation, EURASIP Jouranl on Applied Signal Processing, Vol. 2006, Article ID 72705, pp.1-11,
[19] Maritime Faculty of Split, on-line: http://www.pfst.hr/~ivujovic/znanost.htm#temp_comp,
[20] Kuzmanić, I., Beroš, S.M., Vujović, I: Experimental Results on Visibility Theshold and Calculation of JND Based on Human Visula Perception, Chapter 21 in DAAAM International Scientific Book 2007, B. Katalinic (Ed.), Published by DAAAM International, ISBN 3-901509-60-7, ISSN 1726-9687, Vienna, Austria, DOI:10.2507/daaam.scibook.2007.21, pp. 229-242.