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Thesis Evaluation

Tel.. (030) 314 25799 Datum: 20.02.25 / Bo

Title of the Dissertation.
Analysis and Compression of Dynamic Speckle

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Submitted to:
Bulgarian Academy of Sciences
Institute of Optical Material & Technologies

for the degree of:

Doctor of Philosophy

1 Subject and Significance

This dissertation addresses the field of dynamic speckle imaging (DSI)—a coherent optical technique harnessing the light-scattering properties of various materials to monitor micro-scale processes in real time. Coherent laser illumination leads to random interference patterns, or "speckles," which fluctuate over time when processes such as drying, bacterial growth, or material deformation occur within a sample. By measuring and analyzing these fluctuations with dedicated algorithms, dynamic speckle imaging provides a non-destructive, full-field method for diagnosing or characterizing physical and biological changes in diverse settings.

From an industrial perspective, DSI offers a robust, low-cost, and sensitive approach for detecting subtle defects in materials long before they become macroscopically visible. This can significantly enhance quality control in manufacturing, predictive maintenance, and reliability assessments for materials under mechanical, thermal, or environmental stresses.

The thesis provides new insights into the fundamental behavior of complex systems, combining optical physics, statistics of random fields, and data analytics to tackle real-world problems in this domain. Furthermore, the large data volumes generated by high-speed imaging pose substantial challenges for storage and processing, making data compression of dynamic speckle patterns a key topic. This dissertation addresses both the fundamental and applied facets of DSI—bridging theory with practical, industry-driven applications.

The thesis encompasses a body of 130 pages plus references and list of published papers and conference presentations. The list of citations provides 110 papers from other authors. It appears that the state-of-the-art is adequately reflected.

2. Published and Submitted Papers

Major aspects of the scientific work of the thesis have already been published in 8 high profile peer reviewed journals and conference proceedings. This is an excellent outcome of the thesis work.

3. Organization of the Thesis and Its Contributions

Chapter 1 provides an introduction to the field and literature review. An overview of Dynamic Speckle Imaging provides an excellent theoretical background of speckle phenomena and the statistical foundations for describing speckle intensity fluctuations.

Key works such as Goodman [5], Briers and Webster [7], and various laser speckle contrast-based methods are outlined. The chapter details important industrial and biomedical applications—ranging from blood flow monitoring to defect detection in ceramics.

The chapter highlights persistent challenges in DSI and motivates the areas of the thesis main contributions: (i) variations due to non-uniform illumination; (ii) the need to process enormous amounts of data; (iii) robust, rapid, and portable solutions for on-site inspections.

Chapter 2 focuses on the analysis of dynamic speckle imaging. The very extensive experimental framework is very thoroughly investigated and discussed. Thesis main contributions and results are in the following fields.

Normalization under Non-Uniform Illumination. Many existing algorithms assume uniform laser beam profiles. The dissertation introduces novel or improved normalization methods (e.g., Normalized Temporal Correlation Function variants) to handle Gaussian or irregular beam shapes. The results are impressive.

Temporal Resolution Enhancement: It is investigated how to optimize the frame rates and correlation intervals to capture dynamic processes more accurately

Noise Impact in Outdoor and Harsh Environments: Extensive simulations and real-data analyses show how ambient light and vibrations reduce measurement accuracy, with proposed techniques for mitigating these artifacts.

The above investigations provide novel insight into the field with results that surpass existing strategies in parts significantly This is an impressive body of work which will impact the science in this field.

Chapter 3 investigates the compression of dynamic speckle images. The main motivation is the vast amount of data that is generated in the experiments. Data compression provides means to reduce the amount of data for storage and transmission. This is an important field of research worldwide. Compressing of speckle images is a very unique field of research and there is hardly any prior art that gives hints for suitable approaches. In addition, it is not necessarily the quality of the speckle images that is relevant, but the quality of the resulting activity map.

JPEG and JPEG2000 in Speckle Analysis: The author experimentally evaluates classic image-compression schemes, quantifying how JPEG compression artifacts impact on speckle-based activity maps. This work illustrates benefits of the use of JPEG transform and wavelet coding approaches. SVD-Based Compression: Novel algorithms based on the Singular Value Decomposition (SVD) are proposed, demonstrating substantial reductions in data size while preserving critical activity patterns. PCA-Based Compression with Autoencoding: A principal component analysis approach, augmented by autoencoder principles, achieves high compression ratios without compromising diagnostic accuracy.

Comprehensive comparisons highlight each method's trade-off in compression ratio, computational cost, and reconstruction fidelity for dynamic speckle data. The chapter work is very well outlined and investigated and provides excellent novel insight into how compression impacts specific speckle imagery In particular the novel speckle image "rate vs activity map quality" approach is very intriguing, the introduction of an autoencoder for this task very innovative.

In **Chapter 4** the applications of dynamic speckle imaging in non-destructive testing is investigated. A Portable Smartphone-Based Setup is introduced that allows portable field application. The author details a smartphone-driven DSI system equipped with a small laser module, capturing real-time paint-drying processes, polymer curing, and early-stage microcracks on surfaces. This addresses a key industrial request for mobile, accessible NDT solutions.

Results are presented for high-speed impact testing on composites. Using a high-frame-rate camera, the dissertation investigates gas-gun impact on composite samples. It correlates dynamic speckle activity with mechanical strain and damage progression—comparing DSI with Digital Image Correlation (DIC) for verification.

For hidden defect detection the system's ability to reveal barely visible cracks or delaminations in samples is investigated. Results underscore the method's commercial viability and scientific soundness for advanced materials testing.

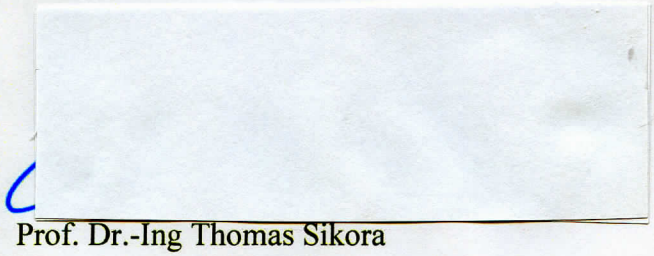
The above chapters already provide sufficient summary and conclusions on the dedicated topics. A separate additional summary and conclusion chapter is indeed superfluent and not required. The author thus finishes the thesis chapters with a short outline of the **thesis's contributions**.

4. Reviewers Summary and Conclusion

Collectively, these contributions advance the state of the art in dynamic speckle imaging, both theoretically—through in-depth statistical and algorithmic studies—and practically, through real-world demonstrations in non-destructive testing. The work stands out for its multidisciplinary approach, merging optical physics, signal processing, software engineering, electronics, mechanics and mechanical testing in a coherent research narrative.

With the depth of research, the extensive experimental validations, and the relevance of the developed solutions for industrial, biomedical, and scientific applications Mr. Levchenko has made significant and original contributions to the field. The methods and results provided form a solid basis for future innovations in robust, real-time speckle metrology.

This dissertation surpasses the typical requirements for a PhD thesis. I evaluate his theses as "very good" and acceptable for awarding the degree of Doctor of Philosophy (PhD).



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