Halmstad University
The Academy for Business, Innovation and Sustainability
Professor B.-G. Rosén
Box 823
SE-301 18 Halmstad
Sweden

Report on:

Thesis ***"Surface Topography and Multiscale Complexity: A Study from Materials to Works of Art"*** by ***François Berkmans,*** UNIVERSITÉ POLYTECHNIQUE HAUTS-DE-FRANCE and INSA HAUTS-DE-FRANCE and POZNAN UNIVERSITY OF TECHNOLOGY

Executive summary:
With the support of the report submitted on my assessment of the thesis for a PhD, by **François Berkmans**, am I concluding that the I hereby declare that the doctoral dissertation meets the requirements of the Act of July 20, 2018 - Law on Higher Education and Science (Journal of Laws 2018, item 1668) and I request that it be admitted for public defense.

1. Background

With the support of :

- A thesis .pdf document "*Surface Topography and Multiscale Complexity: A Study from Materials to Works of Art*", 269p supplied by François Berkmans.

Have the undersigned performed the assessment and written the report.

The report is divided up into the following parts:

Executive summary
1. Background
2. The Thesis in general
3. The Chapters of the thesis -brief summary and quality
4. General conclusion of the work -quality, scientific contribution
5. Final conclusion and rapporteurs opinion

2. The Thesis in general

The thesis in general is based on the development and application of a unified framework—the *Surface Information Acquisition Spectrum (SIAS)*—for analysing surface topography and multiscale complexity in both engineering and art. Across six chapters, it combines theoretical, computational, and experimental approaches to describe, measure, and interpret surface phenomena through non-destructive, quantitative methods.

The introductory chapter establishes the theoretical and metrological foundations of surface analysis and proposes an original *ontology-based terminology* for standardized surface description. Chapter 2 applies this linguistic framework to heraldry, modelling coats of arms as multiscale systems and demonstrating a statistical law of complexity. Chapter 3 introduces numerical modelling with the Koch snowflake to assess fractal computation errors and define a reliable evaluation protocol.

Chapter 4 presents a new *Gaussian-filtered, multi-scale Sdr method* validated by Bootstrap and ANOVA for industrial surfaces, while Chapter 5 extends this protocol to artistic works such as Van Gogh's paintings, revealing its cross-disciplinary potential. The concluding discussion highlights the originality and applicability of the SIAS framework for future developments in mechanical engineering and heritage science.

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3. The Chapters of the thesis -brief summary and quality

Chapter 1: Description of Surface Topography

- Terminology of surface metrology, Ontology development, Measurement technologies, Standards (ISO 25178, ASME B46.1, DIN 4761), Morphomeca philosophy.

Summary:

The opening chapter establishes the scientific and conceptual foundations of the thesis by presenting a comprehensive state-of-the-art in surface metrology. It reviews the terminology, standards, and instrumentation used to describe and measure surface topography, ranging from focus-variation microscopy and coherence-scanning interferometry to the classification logic of ISO 25178.

The chapter identifies inconsistencies in current vocabularies and introduces an original, phenomenon-centred "language" in OWL 2 to unify and formalize surface-related terminology across disciplines.

Supported by extensive references, this section connects linguistic, technological, and methodological aspects of surface characterization and defines the basis for the following chapters.

Quality:

This initial chapter is a high-quality, exhaustive synthesis of the theoretical and methodological background in surface metrology. It demonstrates deep familiarity with both industrial and academic standards and a strong capability for conceptual integration.

The literature coverage—spanning historical sources to the latest ISO updates—provides a robust foundation for the thesis's later developments and confirms the author's command of the mechanical-engineering domain.

Chapter 2: Complexity of Heraldic System

- Heraldic system complexity, Statistical modelling, Zipf's law, Information compression, 2.5D surface analogy, Quantitative methodology

Summary:

Building on the conceptual framework defined in Chapter 1, this chapter introduces an original and interdisciplinary methodology by treating heraldry as a 2.5-dimensional surface system.

Coats of arms are analysed as structured visual languages governed by formal rules. A quantitative model for heraldic complexity is developed, translating visual and symbolic content into measurable informational units such as colour, partition, and charge.

Two large historical corpora are statistically evaluated, demonstrating that the distribution of heraldic complexity follows a Gamma-type law of abbreviation.

The chapter thereby offering a new methodological path for understanding informational complexity in visual systems.

Quality:

This chapter represents a highly innovative and well-executed application of quantitative modelling to a non-traditional dataset.

The author transfers statistical and metrological reasoning to the historical domain, validating the interdisciplinary scope of the thesis.

The mathematical modelling, the use of large data samples, and the clarity of presentation confirm a high level of originality and methodological competence.

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Chapter 3: Von Koch Complexity, -Methods to Compute Fractal Dimensions of Fractal Curves

• Von Koch snowflake, Fractal analysis, Richardson's method, Sampling artefacts, Error model, Scale calibration, Gaussian filtering

Summary:
Based on the conceptual groundwork of the previous chapters, this part of the thesis introduces a controlled, numerical study using the Von Koch snowflake to evaluate fractal-dimension measurements. The author show how traditional Richardson-based approaches systematically underestimate curve length when scale alignment is imperfect.

A new error model is proposed that quantifies these deviations. The study also introduces the use of Gaussian low-pass filtering effectively can be used to minimise aliasing and noise.

The chapter thus establishes a validated computational protocol for surface-complexity analyses in real materials.

Quality:
This chapter represents a well-structured numerical investigation with clear methodological innovation. The modelling work demonstrates analytical skills and a grasp of fractal geometry principles.

The proposed calibration framework is original, and directly transferable to practical surface-metrology applications.

The results provide a solid quantitative foundation for the following more experimental chapters.

Chapter 4: New Fractal-based Method
Using the Sdr parameters from ISO 25178-2 and Gaussian filter

- Multi-scale Sdr method, Gaussian filtering, Bootstrap statistics, ANOVA analysis, Surface complexity quantification, Grit-blasting application

Summary:
Building on the calibrated numerical foundations from Chapter 3, this chapter introduces and validates a new fractal-based surface-analysis methodology for real engineering materials. The approach combines the ISO 25178-2 Sdr parameter with multi-scale Gaussian filtering to quantify surface complexity across different observation scales.

The method is experimentally applied to grit-blasted and machined metal surfaces, successfully identifying process-dependent topographical features and demonstrating its industrial relevance.

This chapter demonstrate the SIAS framework as a practical method for quantitative evaluation of surfaces.

Quality:
Chapter 4 demonstrates excellent experimental design, precise data handling, and high-level integration of statistical and metrological techniques.

The new Gaussian-filtered Sdr methodology represents a clear scientific advancement in surface characterization, providing improved.

The validation through multiple datasets confirms the methodological competence and the practical impact of the work for mechanical engineering applications.

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Chapter 5: Van Gogh and Fractal
A New Perspective for Surface Topography in Art

- Van Gogh impasto surfaces, Fractal dimension in art, Sdr–Gaussian filter methodology, Image-to-topography conversion, Authentication potential

Summary:
Extending the validated metrological methodology to the field of cultural heritage, this chapter applies the *multi-scale Sdr and Gaussian filter approach* to the analysis of Vincent van Gogh's painting surfaces.

High-resolution photographic data are converted into 3D topographies via grey scale conversions, enabling the quantitative study of the surface complexity. Fractal dimension and Sdr values are used to characterize and to distinguish between Van Gogh's authentic and disputed works.

The approach demonstrates that techniques developed for industrial surface metrology can reveal stylistic features in art, linking engineering measurement methods to aesthetic interpretation. The chapter thus illustrates well the interdisciplinary reach of the *Surface Information Acquisition Spectrum (SIAS)* framework.

Quality:
This final research chapter displays originality, creativity, and strong interdisciplinary integration. The adaptation of engineering-grade surface analysis to artistic materials is methodologically sound and demonstrates both technical precision and conceptual depth.

The results are clearly presented, statistically supported, and of high potential value for art authentication and conservation.

The chapter stands out as a convincing demonstration of the thesis's scientific maturity and the versatility of the developed methodology.

Chapter: General Conclusion

- SIAS framework synthesis, Interdisciplinary validation, Methodological innovation, Future perspectives, Scientific and cultural relevance

Summary:
The concluding chapter synthesizes the results from all previous sections into a coherent methodological and conceptual framework: the *Surface Information Acquisition Spectrum (SIAS)*.

It integrates linguistic, statistical, fractal, and metrological approaches into a unified model for describing and quantifying surface complexity across multiple scales. The author summarizes how each tier of the SIAS—from ontology-based terminology to quantitative Gaussian-filtered Sdr analysis—builds a continuous chain linking from perception, to visualization, and numerical evaluation.

The final discussion highlights the successful application of the framework to both industrial materials and artistic surfaces, demonstrating its broad scientific and cultural reach.

Future perspectives again underlines the scientific perspective and maturity including automation, AI-assisted surface annotation, and expanded interdisciplinary collaboration.

Quality:
The general conclusion effectively consolidates the thesis's theoretical, methodological, and applied achievements.

It demonstrates a high degree of synthesis and scientific maturity, reflecting both depth of understanding and clarity of vision for further research.

The chapter closes the work convincingly, emphasizing the originality, coherence, and future potential of the SIAS framework as a lasting contribution to mechanical engineering and cross-disciplinary surface analysis.

4. General conclusion of the work -quality, scientific contribution

The thesis work of **François Berkmans** is unquestionably a high-quality and original research contribution within the discipline of **Mechanical Engineering**, addressing the characterization of **surface topography and multiscale complexity** in both industrial and artistic contexts. The scientific achievements centre on the development of the *Surface Information Acquisition Spectrum (SIAS)* framework, which unifies theoretical, computational, and experimental methods into a coherent approach for describing and quantifying surfaces.

The work clearly demonstrates the candidate's **comprehensive theoretical knowledge** in surface metrology, fractal analysis, and measurement science, as well as a strong **ability to conduct independent and interdisciplinary research**. The thesis successfully combines analytical modelling, statistical validation, and practical experimentation, thereby fulfilling the expectations of Criterion A.

In line with Criterion B, the research provides **original scientific solutions** to relevant and complex problems. The proposed *Gaussian-filtered Sdr methodology*, the *error-controlled fractal-dimension model*, and the *ontology-based surface terminology* represent novel and validated contributions to the field. Moreover, the innovative extension of these engineering tools to **art surface analysis**—such as the quantification of Van Gogh's work—demonstrates creativity, societal relevance, and the application of engineering science beyond its traditional domain.

The empirical and computational studies are rigorously executed, clearly presented, and supported by solid statistical evidence. The language, structure, figures, and references are consistently of a high academic standard. The thesis not only compiles and critically analyses a wide range of relevant literature but also opens new **research and application perspectives** for surface metrology, industrial design, and cultural science.

5. Final conclusion and rapporteurs opinion

I hereby declare that the doctoral dissertation meets the requirements of the Act of July 20, 2018 – Law on Higher Education and Science (Journal of Laws 2018, item 1668) and I request that it be admitted for public defense.

Halmstad 2025-10-30

Bengt-Göran Rosén, *MSc, Lic. Eng., Ph.D., Docent*
professor in Mechanical Engineering at Halmstad University, Sweden

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