



Julie Marteau  
Associate professor of mechanics  
Mechanical Department  
Laboratoire Roberval  
Université de Technologie de Compiègne

### External examiner report on doctoral dissertation for PhD Degree

**Institution:** Université Polytechnique Hauts-de-France (UPHF), INSA Hauts-de-France, Poznań University of Technology

**Subjects:** mechanics of solids, materials, structures and surfaces (UPHF), Mechanical engineering (Poznań) and History and Civilizations: history and archeology of ancient and medieval worlds, art (UPHF)

**Name of the PhD candidate:** François BERKMANS

**Title of thesis:** Surface topography and multiscale complexity: a study from materials to works of art

#### Dissertation supervisors:

Bigerelle Maxence, Professor, LAMIH UMR CNRS 8201, Université Polytechnique Hauts-de-France, Valenciennes, France

Wieczorowski, Michał, Professor, Poznań University of Technology, Poznań, Poland

The overall goal of the thesis is to study the informational complexity of a spectrum called the 'Surface Information Acquisition Spectrum' (SIAS) thus addressing several issues affecting the field of surface metrology. A methodological approach is proposed by linking the notion of complexity to fractals. The investigated topic requires dealing with very diverse notions (language, image syntax, visualization artefacts caused by discretization, fractals...) and this diversity is also present in the applications going from a mathematical construction (the Koch snowflake) to engineering surfaces (grit-blasted surfaces) to paintings.

The dissertation comprises 226 pages, two appendices (10 pages) followed by references and an abstract (in French, Polish and English). The thesis consists of a general introduction followed by five chapters

and a general conclusion. Chapter 1 deals with the qualitative description of surface topography, thus occupying the “language” tier of the Surface Information Acquisition Spectrum (SIAS). It highlights the fragmentation of existing terminology in surface metrology and proposes a shift by consolidating scattered descriptors through Web Ontology Language (OWL). Chapter 2 delves into surface systems to focus on the “visual - syntax” tier of the SIAS. Through the study of heraldic surfaces, it seeks to test the ability of quantitative descriptors to capture heraldic complexity. Chapter 3 focuses on the testing of methods to compute fractal dimensions of fractal curves, using the classic Koch snowflake as a didactic test case. It aims at going from the “visual-syntax” tier to the “quantitative evaluation” tier of the SIAS. Chapter 4 is firmly part of the “quantitative evaluation” tier. It compares the Richardson Patchwork method to the coupling of an ISO 25178-2 roughness parameter called the developed area ratio (Sdr) with a low-pass Gaussian filter for multiscale characterization. The defined protocol is applied to ‘real’ surfaces (measured on grit-blasted specimens) with different bootstrapping methods in order to find a relevant scale linking the relative area and blasting pressure. Chapter 5 proposes a new perspective for surface topography in art through the application of the developed protocol to Van Gogh paintings to test if the painter’s signature can be identified; thus, going back to meaning in the SIAS. Finally, general conclusions are given: the philosophy and results of each chapter are synthesized before giving a few prospects for the next three years.

The structure of the dissertation is coherent and flows logically from chapter to chapter, even when it is disrupted by the use of articles instead of ‘traditionally PhD written’ sections. The style of writing is very clear. The candidate managed to present different theories and results in a pleasant and readable way, which was probably not easy as it combines different fields. The candidate not only managed to convey his general theoretical knowledge in the discipline of Mechanical Engineering but also show his knowledge of other fields.

I will now detail some specific points for each chapter.

In Chapter 1, the candidate focuses on the semantic relationship between the signifier and the signified. The semiotic triangle is presented and different concepts are defined (terminology, texture, roughness, form, waviness...). An overview of the areal surface texture parameters is given, even though it is not really used afterwards. Two measurement devices are described (focus variation microscope and coherence scanning interferometry). A white-light interferometer is indeed used in Chapter 4 to examine the grit-blasted surfaces. Then, the candidate proposes a state of the art on surface metrology terminology by first examining standardized vocabulary (DIN 4761 standard, ISO 8785, ISO 25175-2, ASME B.46-1) and then non-standardized terminology through a corpus-based analysis (a little over 100 articles were used). It would have been interesting to specify a main field for each article in Appendix A so that the reader has a better view of the diversity of terms for each field. Then, the candidate proposes a first classification of the identified terms by grouping them into four categories: geometrical or morphological descriptors, terms referring to topographical discontinuities or structures, descriptors of spatial organization and finally terms associated to phenomena derived from or associated to manufacturing processes. Several limits are highlighted. To address the identified limitations, the authors developed an ontology based on OWL 2. The ontology is well introduced but the choices (and the associated robustness) of the classes and sub-classes can be difficult to trace. It would be interesting

to know if this method was tested by different people (how many, which profiles), if the candidate had an end-user in mind or on how many surface examples the ontology was tested (three are shown). Were these three surfaces chosen for their didactic qualities? The discussion of this chapter is rich and arises relevant issues linked to the topic. As the candidate experienced French, Polish and English influences, it would have been interesting to have his input on the influence of the language on the terminology (and associated analysis).

Chapter 2 uses coats of arms as 2.5D surfaces to explore syntax and information complexity. First, heraldry is defined and its historic context is presented before diving in its vocabulary and syntax specificities. It is worth noting that the shield was discarded from the analysis. This was surprising at first as it seems to rely a piece of information and is not purely aesthetic. It is specified that it is "not of interest as information in our mode of thought". It rather seems that this choice is dictated by the two corpora chosen to carry out his experiment. Then, a discrete model is proposed to assess heraldic complexity. It is concluded that heraldry follows the principle of economy as expressed by Zip's law of brevity. The followed approach is original and paves the way towards the identification of descriptors for digitized geometry (next chapter).

Chapter 3 uses the Koch snowflake to examine how sampling density, indentation geometry and mesh choices affect fractal estimates. First, fractals are defined. The terms in the equation written p.92 need to be properly defined to avoid any confusion. The evaluation of the fractal pattern of the Von Koch Island using Richardson's method is presented by including an article published in *fractal and fractional* in which the candidate is the second author. More specifically, numerical artefacts introduced by Richardson's method are examined through the testing of eight different calculation methods. Even though, the dependency of the estimated fractal dimension on the chosen algorithm is highlighted, Richardson's method remains effective in estimating the fractal dimension of self-similar structures. At the end of the analyses of the stochastic Von Koch flake, the extension of the He-Liu formulation originally developed for porous materials is mentioned and then developed in Appendix A. Despite being a promising venue of work, this model is no longer used in the following parts. The conclusion of this chapter does not match its content. In particular, it is noted that it "validates a Gaussian low-pass pre-filter as the most effective way to suppress aliasing without erasing scale information" (p.122). This validation part should be added or the corresponding conclusive remarks removed.

Chapter 4 first introduces the bootstrap methodology in details, despite its use in Chapter 2, and presents the concept of analysis of variance. The introduction of the example of surface study at p.128 is on first reading a bit awkward but then makes sense when reading the articles. It would probably be best to mention the case study in the prolegomena of Chapter 4. It would also allow the candidate to explain this application case choice. The 'parameter rash' is mentioned and then the relevance of the Sa parameter is partially discussed: methods to ensure the validity of the ANOVA are mentioned without really properly showing the ANOVA results and the next section focuses on another parameter (Sdr). A few explanations are missing in between 4.2 and 4.3.

Then, a first article is included in this chapter. This article was published in *materials* and the candidate is first author. This article compares Richardson's patchwork with the computation of the Sdr parameter with low-pass filtering through the assessment of the relative area calculated on topographies of TA6V samples grit-blasted with different pressures and blasting media. The provided comparison is interesting but the investigated surfaces, even though real, are not really representative of the complexity that can

be faced when treating topographies. In particular, it would be interesting to discuss the robustness of these methods when dealing with missing points (for example for surfaces having high slopes). A second article is included in this chapter. It was published in *fractal and fractional* and the candidate is first author. In this article, Richardson patchwork with the computation of the Sdr parameter with low-pass filtering is compared again. These methods are used to determine the relationship between the relative area and blasting pressure. An original topic is the comparison of three bootstrapping methods (simple bootstrap, double bootstrap based on pair replication and double bootstrap based on residuals) for this assessment.

In Chapter 5, the Sdr-Gaussian protocol defined in the previous chapter is applied to pictorial surfaces (Van Gogh paintings). More specifically, very high resolution images of paintings are converted into topographic data. Then, the overall fractal dimensions of eight undisputable Van Gogh artworks are computed, as well as the dimensions associated to specific details. Then, another two paintings are assessed: one recently authenticated and another one now considered as forgery. The results obtained for these two paintings confirm that fractal complexity can serve as a reliable metric for artistic attribution and authentication. Very few details are given on the high resolution images of the paintings or on the methodology used to select the specific details that were chosen for the investigation. Giving details would be helpful for future applications of the detailed protocol. In particular, the impact of the definition of these images on the results would be interesting to discuss. This chapter also contains an article, which is currently in the process of peer review in *Surface Topography: Metrology and Properties*. This article mentions a previous study of Van Gogh paintings using wavelets. It would have been interesting to further discuss the pros and cons of each method. The use of Van Gogh paintings for testing such methodologies is discussed in the conclusion of the chapter and underlines the impact of Van Gogh's painting technique on the results. This point is interesting and highlights how the candidate is able to take a step back from his analyses.

The general conclusion gives a good summary of the main discussions and results. The candidate, through his dissertation, managed to propose an original solution to a scientific problem. A few prospects are given for the ontology, heraldic applications and the running of the full SIAS by industrial and museum partners. These trajectories are realistic even though some precisions could have been given.

**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.**

Compiègne, October 28, 2025

Julie Marteau

