COURSE DESCRIPTION CARD - SYLLABUS

Course name
MULTISCALE METROLOGY

Course

Proposed by Discipline
Mechanical engineering
Type of studies
Doctoral School
Form of study
full-time

Year/Semester
II/3, III/5
Course offered in
English
Requirements
elective

Number of hours

Lecture
4

Tutorials

Projects/seminars

Number of credit points

1

Lecturers

Responsible for the course/lecturer:
prof. Christopher A. Brown
email: brown@wpi.edu
phone: 001 508 560 6986
Name of the university: Worcester Polytechnic Institute University
address 100 Institute Rd.
Worcester, Massachusetts, 01609
USA

Responsible for the course/lecturer:

Prerequisites

Knowledge: Undergraduate physics and math for engineers.

Skills: Word processing and spread sheets.

Social competencies: critical thinking and creative discussion.

Course objective

In the abstract, the objective is to expand student's perspective on science and technology so they can appreciate the use of reductionism and connecting commonalities to solve a class of problems. Specifically, the objectives are to learn how the determination of value adding multiscale geometric characterization was developed for the irregular geometries, which are part of all surfaces, particularly at fine scales; to use reductionism to understand topographically related interactions; to formulate new axioms based on observed commonalities; and to think critically in assessing scientific and technical literature.

Course-related learning outcomes

Knowledge

A PhD student who graduated from doctoral school knows and understands: Measurement, analysis and characterization of irregular topographies to discriminate and to relate processing, geometric properties, and functionality and how to use results to provide value in a variety of applications.
1) global achievements, covering theoretical foundations as well as general and selected specific issues that are relevant to scientific disciplines studied at the Doctoral School, to the extent that enables revision of existing paradigms, [P8S_WG/SzD_W01]
2) key developmental trends of disciplines of science in which education at the Doctoral School takes place, [P8S_WG/SzD_W02]
3) scientific research methodology in disciplines represented at the Doctoral School, [P8S_WG/SzD_W03]
4) principles of disseminating results of scientific activity, also in an open access mode, [P8S_WG/SzD_W04]
5) fundamental dilemmas of the contemporary civilization, [P8S_WK/SzD_W05]
6) economic, legal, ethical and other vital conditions related to scientific activity, [P8S_WK/SzD_W06]
7) basic principles of knowledge transfer to the economic and social sphere as well as those of commercialization of results of scientific activities and knowhow related to these results. [P8S_WK/SzD_W07]

Skills

A PhD student who graduated from doctoral school can: Design experiments to determine how to discriminate different topographies to support quality control and forensics, and to find functional correlations with processing and performance to support product and process design.
1) use knowledge from different branches of science to creatively identify, formulate and innovatively solve complex problems or to perform research tasks such as: - define the aim and subject of scientific research, form a research hypothesis, - develop research methods, techniques and tools and use them creatively, - draw conclusions on the basis of research results, [P8S_UW/SzD_U01]
2) critically analyze and assess scientific research results, work of experts and other creative activities together with their contribution into knowledge development, [P8S_UW/SzD_U02]
3) transfer the results of scientific activity to the economic and social sphere, [P8S_UW/SzD_U03]
4) communicate on specialist issues on the level that allows active participation in the international scientific community, [P8S_UK/SzD_U04]
5) share results of scientific activity also in a popular form, [P8S_UK/SzD_U05]
6) initiate debates, [P8S_UK/SzD_U06]
7) take part in scientific discourse, [P8S_UK/SzD_U07]
8) use the English language on at least B2 level, according to the Common European Framework of Reference for Languages (CEFR), to a degree which allows active participation in the international scientific and professional community, [P8S_UK/SzD_U08]

9) plan and implement individual and team research projects, also in the international community, [P8S_UK/SzD_U09]
10) independently plan and act for their self-development as well as inspire and organize development of others, [P8S_UK/SzD_U10]
11) plan classes and groups of classes and conduct them with the use of up-todate methods and tools [P8S_UK/SzD_U11]

Social competencies

A PhD student who graduated from doctoral school is ready to: Supervise and teach others to provide value from multiscale geometric analyses.
1) critically assess achievements within a given scientific discipline, [P8S_KK/SzD_K01]
2) critically evaluate their own contribution to development of a given scientific discipline, [P8S_KK/SzD_K02]
3) acknowledge the importance of knowledge in solving cognitive and practical problems, [P8S_KK/SzD_K03]
4) fulfilling the social obligations of researchers and creators, [P8S_KO/SzD_K04]
5) initiate actions in the public interests, [P8S_KO/SzD_K05]
6) think and act in an entrepreneurial manner, [P8S_KO/SzD_K06]
7) maintain and develop the ethos of research and creative communities, including: - conducting independent scientific activity, - respecting the principle of public ownership of the results of scientific activities, including the principles of intellectual property protection. [P8S_KR/SzD_K07]

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

PQF code	Methods for verification of learning outcomes	Assessment criteria
W01, W02, W03, W04, W05, W06, W07	Recognition of effective measurement, characterization, and analysis methods for irregular topographies.	Effectiveness
U01, U02, U03, U04, U05, U06, U07, U08, U09, U10, U11	Formulation of effective experimental methods for discriminating irregular topographies and finding functional correlations.	Appropriateness
K01, K02, K03, K04, K05, K06, K07	Critiquing technical papers and discussion based on fundamental principles	Articulation and application of principles

Programme content

Theory and methods for advancing surface metrology leading to multiscale analyses and pertinent geometric characterization to provide value by quantifying relations between surface topographies and their processing and between performance and surface topographies.

Course topics

The natures of irregular topographies, scientific reductionism applied to surface metrology, opportunities to provide value beyond basic surface metrology, discrete interaction theory, fundamental scales of topographic interactions, principles for advanced surface metrology, multiscale geometric characterizations, multiscale regression analyses, coefficients of determination versus scale, multiscale discrimination tests. Mean square ratio versus scale. Applications of advanced surface metrology.

Teaching methods

Lecture and discussion

Bibliography

Basic

1. Brown, C. A. (2024). Fractal-Related Multiscale Geometric Characterisation of Topographies. In *Characterisation of Areal Surface Texture* (pp. 151-180). Cham: Springer International Publishing.
2. Brown, C. A. (2021). Surface metrology principles for snow and ice friction studies. *Frontiers in Mechanical Engineering*, *7*. https://doi.org/10.3389/fmech.2021.753906
3. Brown, C.A., Charles, P. D., Johnsen, W. A., & Chesters, S. (1993). Fractal analysis of topographic data by the patchwork method. *Wear*, *161*(1–2), 61–67. https://doi.org/10.1016/0043-1648(93)90453-s
4. Brown, C. A., Hansen, H. N., Jiang, X. J., Blateyron, F., Berglund, J., Senin, N., Bartkowiak, T., Dixon, B., Le Goïc, G., Quinsat, Y., Stemp, W. J., Thompson, M. K., Ungar, P. S., & Zahouani, E. H. (2018). Multiscale analyses and characterizations of surface topographies. *CIRP Annals*, *67*(2), 839–862. https://doi.org/10.1016/j.cirp.2018.06.001
5. Gleason, M. A., Kordell, S., Lemoine, A., & Brown, C. A. (2013, June). Profile curvatures by Heron's formula as a function of scale and position on an edge rounded by mass finishing. In *14th International Conference on Metrology and Properties of Engineering Surfaces, Taipei, Taiwan, paper TS4-01* (Vol. 22).
6. Peta, K., Love, G., & Brown, C. A. (2024). Comparing repeatability and reproducibility of topographic measurement types directly using linear regression analyses of measured heights. *Precision Engineering*, *88*, 192-203.https://doi.org/10.1016/j.precisioneng.2024.02.009
7. Vulliez, M., Gleason, M. A., Souto-Lebel, A., Quinsat, Y., Lartigue, C., Kordell, S. P., Lemoine, A. C., & Brown, C. A. (2014). Multi-scale curvature analysis and correlations with the fatigue limit on steel surfaces after milling. *Procedia CIRP*, *13*, 308–313. https://doi.org/10.1016/j.procir.2014.04.052
8. Bartkowiak, T., Etievant, D., & Brown, C. A. (2024). Multiscale slope analysis and functional correlation with gloss reflectance from photographic papers, Surface Topography: Metrology and Properties.
9. Bartkowiak, T. and Brown, C.A., 2018. A Characterization of Process–Surface Texture Interactions in Micro-Electrical Discharge Machining Using Multiscale Curvature Tensor Analysis. Journal of Manufacturing Science and Engineering, 140(2), p.021013.

Additional

1. Bartkowiak, T., & Brown, C. (2016). Multi-scale curvature tensor analysis of machined surfaces. *Archives of Mechanical Technology and Materials*, *36*. 10.1515/amtm-2016-0009
2. Bartkowiak, T., Berglund, J., & Brown, C. A. (2018). Establishing functional correlations between multiscale areal curvatures and coefficients of friction for machined surfaces. *Surface Topography: Metrology and Properties*, *6*(3), 034002. https://doi.org/10.1088/2051-672x/aac073

3. Bartkowiak, T., Etievant, D., & Brown, C. A. (2024). Multiscale slope anlysis and functional correlation with gloss reflectance from photographic paper. *Surface Topography: Metrology and Properties*.

Breakdown of average student's workload

	Hours	ECTS
Total workload	25	1,0
Classes requiring direct contact with the teacher	4	0
Doctoral student's own work (literature studies, preparation for tutorials, project preparation) [1]	21	1,0

[1] delete or add other activities as appropriate