Opportunity of Msci Dissertation (Tesi di Laurea)

Title	Development of State-of-Health Indicators for Researchable Batteries Using Deep-Transfer Learning Methods
Motivations and objectives of the research	Rechargeable batteries are, nowadays, the main power storage and supply units of many systems, such as electric vehicles, micro-grids and aerospace crafts [1, 2, 10]. For this, an accurate estimation of the battery State-of-Health (SoH) is fundamental to enhance the performance of the system within which the battery operates, e.g. ensuring its safety, maximizing its availability and reducing sudden breakdowns and failures [3]. A large number of data-driven methods based on shallow and deep learning techniques have been proposed for the estimation of the battery SoH from measured electrical signals [3, 5, 8]. These methods are typically developed using input-output data formed by electrical signal values and the corresponding battery SoH, collected from laboratory (accelerated) tests [4, 9]. However, batteries are typically operated in industrial systems characterized by operational (e.g., loads), environmental (e.g., external temperature) and managemental (e.g., humidity during storage) conditions very different from those of the laboratory tests. For this, the performance of the methods developed using laboratory data tend to be not satisfactory when they are applied to battery operating in real industrial systems [6, 7, 10]. In this context, the objective of the present thesis project is to develop a method for the estimation of battery SoH based on the emerging techniques of Deep Learning (DL) and Transfer Learning (TL). DL allows capturing the representative information from raw input data, providing high-level abstractions of it. TL is emerging as a technique to improve the performance of artificial intelligence models when the distribution of the data used to train the model is different from the distribution of the new (test) data which the models are applied to. Real data collected from battery operating in real industrial systems, containing voltage, currents, and temperature profiles during charging and discharging cycles along the battery life will be used to validate the developed method. The thesis will be developed in collaboration with Ecole Polytechnique (Paris, France).
Activities	• Literature survey of the state-of-the-art method for battery SoH estimation; • Analysis of the possible solution methods; • Selection of the most promising solution method; • Development of the deep-transfer learning method; • Application of the developed method to benchmark datasets; • Analysis of the obtained results.
Required competencies and skills	*i)* Interest in developing innovative algorithms to tackle real applications; *ii)* Good knowledge of Matlab or Python programming or a willingness to learn before starting the assignment.
Composition of the research group	Number of Full Professors: 1 Number of Associate Professor: 1 Number of Postdoc at Ecole Polytechnique (Paris, France): 1
Names of the research director	Enrico Zio

E-mail address, and web-page	Email: enrico.zio@polimi.it Email: piero.baraldi@polimi.it www.lasar.polimi.it www.lasar.polimi.it
Duration of the dissertation	
Total thesis duration	Approximately 9 Months. At most 1 pending exam.

Starting date: April 2021

[1] X. Li, C. Yuan, X. Li and Z. Wang, "State of health estimation for Li-Ion battery using incremental capacity analysis and Gaussian process regression," *Energy,* vol. 190, p. 116467, 2020.

[2] K. Goebel, B. Saha, A. Saxena, J. R. Celaya and J. P. Christophersen, "Prognostics in Battery Health Management," *IEEE Instrumentation & Measurement Magazine,* vol. 11, pp. 33 - 40, 2008.

[3] G.-w. You, S. Park and D. Oh, "Real-time state-of-health estimation for electric vehicle batteries: A data-driven approach," *Applied Energy,* vol. 176 , p. 92–103, 2016.

[4] Y. Fan, F. Xiao, C. Li, G. Yang and X. Tang, "A novel deep learning framework for state of health estimation of lithiumion battery," *Microelectronics Reliability,* vol. 32, p. 101741, 2020.

[5] C. Vidal, P. Malysz and P. Kollmeyer, "Machine Learning Applied to Electrified Vehicle Battery State of Charge and State of Health Estimation: State-of-the-Art," *IEEE Access,* vol. 8, p. 52796, 2020.

[6] L. Wang, C. Pan, L. Liu, Y. Cheng and X. Zhao, "On-board state of health estimation of LiFePO4 battery pack through differential voltage analysis," *Applied Energy,* vol. 168 , p. 465–472, 2016.

[7] Y. Li, M. Abdel-Monem, R. Gopalakrishnan, M. Berecibar, E. Nanini-Maury, N. Omar, P. d. Bossche and J. Van, "A quick on-line state of health estimation method for Li-ion battery with incremental capacity curves processed by Gaussian filter," *Journal of Power Sources,* vol. 373, pp. 40-53, 2018.

[8] Y. Li, K. Li, X. Liu and L. Zhang, "Fast battery capacity estimation using convolutional neural networks," *Transactions of the Institute of Measurement and Control,* vol. in press, pp. 1-14, 2020.

[9] X. Chen, L. Ye, Y. Wang and X. Li, "Beyond Expert-Level Performance Prediction for Rechargeable Batteries by Unsupervised Machine Learning," *Adv. Intell. Syst.,* vol. 1, p. 1900102, 2019.

[10] T. Gao and W. Lu, "Machine learning toward advanced energy storage devices and systems," *iScience,* vol. 24, p. 101936, 2021.