



UNIVERSITÀ DI PISA
DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE
Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

“Mastering Machine Learning Techniques: Application to Melanoma Detection”

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Short Abstract: This 8-hour course will cover a comprehensive exploration of machine learning techniques applied to medical imaging, leading towards the early detection of melanoma. The course will cater to a diverse audience, from beginners to intermediate practitioners in machine learning, and will blend theoretical foundations with practical applications.

The course will begin with an overview of the iToBoS EU project, emphasizing the significant role of machine learning in enhancing the accuracy and efficiency of melanoma detection. This will set the stage for the technical content that follows, and highlighting the real-world impact of these technologies in healthcare.

Participants will then be introduced to the foundational concepts of machine learning, starting with linear regression, and their application in predictive analytics. The course will then transition into logistic regression, focusing on classification problems relevant to medical diagnostics.

As the course progresses, it will delve into neural networks, using logistic regression as a stepping stone to understanding neural networks. The progression from logistic regression to neural networks is a natural evolution from simpler linear models to more complex, non-linear models capable of handling a wider range of data and problem types in machine learning.

The course will culminate in an in-depth exploration of Convolutional Neural Networks (CNNs), vital for image recognition and analysis tasks in melanoma detection. Attendees will learn about the architecture of CNNs, their layers and filters, and the application of CNNs to dermoscopic images for melanoma detection.

Furthermore, the course will address the challenge of working with unbalanced datasets in medical imaging. It will introduce specialized evaluation metrics such as Precision, Recall, F1 Score, AUC-ROC, and the Precision-Recall Curve, which are essential for accurately assessing model performance in scenarios where traditional metrics may be misleading.

By the end of this course, participants will have gained a solid understanding of key machine learning concepts and their application in the medical field, particularly in melanoma detection.

Course Contents in brief:

Lecture 1: Learning Models (2 hours)

1. **Overview of the iToBoS project**
 - Early detection of melanoma
2. **Supervised vs Unsupervised Learning**
 - Understanding the structure of the data
 - Differentiating between regression and classification.
3. **Predictive modeling: Linear Regression**
 - Basic concept.
4. **Modeling the hypothesis function**
 - Formulating the hypothesis function.
 - Understanding linear regression parameters.
5. **Cost Function and Gradient Descent**
 - Mean Squared Error cost function
 - Implementing gradient descent.

Lecture 2: Logistic Regression (1 hour)

1. **A linear classifier**
 - Understanding logistic regression for classification.
 - Binary classification examples.
2. **Hypothesis Representation and Decision Boundary**
 - Sigmoid function and interpreting logistic regression output.
 - Concept of decision boundary in logistic regression.
3. **Cost Function in Logistic Regression**
 - Analyzing the cost function.
 - Convex optimization in classification.

Lecture 3: Basics of Neural Networks (2 hours)

1. **Introduction to Neural Networks**
 - Definition and motivation for using neural networks.
 - Overview of non-linear classification.
2. **Perceptrons as Linear Classifiers**
 - Introduction to the perceptron model.
 - Understanding how perceptrons work in linear classification.
3. **From Linear to Non-Linear Boundaries**
 - Limitations of linear classifiers like perceptrons.
 - The need for non-linear classification in complex problems.
4. **Introduction to Neural Network Architecture**
 - Basic components: neurons, weights, biases.
 - Understanding neuron layers and structure.
5. **Learning with Neural Networks**
 - Concept of feedforward and backpropagation.
 - Overview of the training process using examples.

6. Intuition on Backpropagation

- Detailed explanation of backpropagation.
- The significance of training neural networks.

Lecture 4: Advanced Concepts and Convolutional Neural Networks (2 hours)

1. Deep Dive into Backpropagation

- In-depth analysis of the backpropagation process.
- Computational graphs and gradient computation.

2. Understanding Convolutional Neural Networks (CNNs)

- Distinction between Fully-Connected Networks (FCNs) and CNNs.
- The architecture and operation of CNNs.

3. Components of CNNs

- Convolutional layers, activation functions, and pooling.
- Importance of ReLU, softmax functions, and dropout layers.

4. Training and Optimizing CNNs

- Forward and backward propagation in CNNs.
- Strategies to address vanishing/exploding gradients.

5. Application of CNNs in Image Recognition

- How CNNs achieve feature extraction in image classification.
- Practical examples of CNNs in image recognition.

Lecture 5: Case study for the detection of melanoma (1 hour)

1. Dealing with medical data

- Bias in the data

2. Challenges of Unbalanced Datasets

- Understanding the nature of unbalanced datasets in medical imaging.
- Introduction to Precision, Recall, F1 Score, AUC.

3. Combining different data sources

- Demographic information
- Clinical history
- Genomics

4. Importance of Accurate and Clinically Relevant Models

- Relevant metrics in medical imaging: Sensitivity and Specificity

Total # of hours of lecture: 8 hours

References:

https://rafaelgarciaatudg.blogspot.com/p/publications_19.html

CV of the Teacher

Degrees

- 2001: PhD in Computer Engineering, (Univ. de Girona, Spain).

- 1994: Computer Engineering, (Univ. Autònoma de Barcelona, Spain).

Positions

- 2019-today. Full Professor, Univ. of Girona.
- 2023-today. Director of the Computer Vision and Robotics Institute, Univ. of Girona.
- 2011-2016. Director of the Institute of Education Sciences, Univ. of Girona.
- 2009-2015. Director of the Computer Vision and Robotics Group, Univ. of Girona.
- 2003-today. Director of the Underwater Vision Lab, Univ. of Girona.
- 2003-2011. Vice-dean of the Polytechnic School, Univ. of Girona.
- 2005. Visiting professor, Electrical and Computer Engineering Department, Univ. of Miami, USA.
- 2002-2003. Member of the committee for the evaluation of the Computer Engineering studies.
- 2002-2004. Associate director of the Dept. of Electronics, Informatics and Automation.
- 2003-2019. Tenured University Professor, Department of Electronics, Informatics and Automation, Univ. of Girona.

Recent research grants

- 2021-2024. H2020 Project "iToBoS: Intelligent Total Body Scanner for Early Detection of Melanoma" SC1-BHC-06-2020-965221 (UdG: 1,138,875 €). Project Coordinator (19 partners; Total funding: 12,128,153.75 €).
- 2021-2023. H2020 Project "DeeperSense: Deep-Learning for Multimodal Sensor Fusion" H2020-ICT-2020-2-101016958 (475,000 €)
- 2021-2024. MCIU project "SIREC: Seafloor Intelligent Robot Exploration and Classification" (in Spanish: Robot Inteligente para la exploración y clasificación del fondo marino). PID2020-116736RB-I00 (249,260 €)
- 2018-2022. H2020 Project "EUROFLEETS+: An alliance of European marine research infrastructure to meet the evolving needs of the research and industrial communities" H2020-INFRAIA-2018-1- (228,975 €)
- 2018-2021. MINECO project "UDRONE: Intelligent UnDerwater Robot for Omnidirectional immersive beNthic Exploration". CTM2017-83075-R (226,270 €)
- 2014-2016. MINECO Project "OMNIUS: Light-weight Robot for Omnidirectional Underwater Surveying and Tele-presence". CTM2013-46718-R (UdG: 257,730 €)
- 2013-2017. FP7 EU Project "ROBOCADEMY: European Academy for Marine and Underwater Robotics". FP7-PEOPLE-2013-ITN-608096. (UdG: 226,681 €)
- 2013-2017. FP7 EU Project "EUROFLEETS2: New Operational Steps towards an Alliance of European Research Fleets". FP7-INFRASTRUCTURES-2012-312762 (UdG: 195,190€)
- 2012-2015. MICINN-INNPACTO Project "PICMAR: Intelligent Platform for Multimodal Characterization of the Seafloor and Submerged Structures". IPT-2012-0463-310000 (UdG: 281,441 €)
- 2012-2015. Technology transfer contract with OSSA "PABLITO: Predictive adaptive blasting in tunnel operation" (UdG: 521,438 €)
- 2011-2015. FP7 EU project "MORPH: Marine robotic system of self-organizing, logically linked physical nodes". FP7-ICT-2011-288704 (UdG: 671,580 €)
- 2011-2014. FP7 EU project "PANDORA: Persistent autonomy through learning, adaptation, observation and re-planning". FP7-ICT-2011-288273 (UdG: 534,760 €)
- 2010-2013. Technology transfer contract with the Univ. of Miami (USA). "High Resolution Landscape (2-D) Mosaics for Improved Coral Reef Monitoring Capability" (US\$93,212)
- 2010-2013. MICINN project "MUMAP: Multi-modal 3-D Mapping for the Characterization of the Seafloor using an Autonomous Robot". CTM2010-15216/MAR (227,480 €)
- 2010-2012. US DoE-DoD joint programme (subcontract through the Univ. of Miami). "High Resolution Landscape (2-D) Mosaics for Improved Coral Reef Monitoring Capability" (US\$93,212)

- 2011-2012. Technology Transfer Project "Development of Methods for Predicting 3D Geobodies from Thickness Data: Reconstructing Subsurface Uncertainty Using 3-D Markov Chain Models". Nova Southeastern University (US\$25,220)
- 2010-2012. FP7 EU project "POLMOSAIC - Advanced Underwater Image Mosaicing through Imaging Polarimetry" (160,793 €)
- 2010-2013. FP7 EU project "TRIDENT - Marine robots and dexterous manipulation for enabling autonomous underwater multipurpose manipulation" (461,480 €)
- 2010-2012. Technology Transfer Project "Automatic video categorization system". INDRA SISTEMAS SA, DSET SL and LAVINA SA (152,636 €)

Invited lectures

- 2020: Plenary Talk at the Quantitative Monitoring of Underwater Environment Workshop, Brest, France. Title of the Talk: "Challenges of vision-based robotic ocean exploration".
- 2019: Keynote Speaker at the Underwater 3D Recording & Modelling Workshop, Limassol, Cyprus. Title of the talk: "Omnidirectional Underwater Computer Vision Research and Applications at the University of Girona".
- 2019: Keynote Speaker at the Initiative Bildverarbeitung Schleswig-Holstein, Kiel, Germany. Title of the talk: "Underwater Imaging: using Computer Vision for Mapping in a Participating Media".
- 2018: Keynote Talk at the 15th International Conference on Ubiquitous Robots. Honolulu, Hawaii, USA. Title of the talk: "Towards immersive benthic exploration using intelligent robots".
- 2018: Invited Speaker at the ISIC Skin Image Analysis Workshop and Challenge (MICCAI 2018). Granada, Spain. Title of the talk: "The role of total body photography in skin cancer detection: challenges and opportunities".
- 2017: Invited lecture at the Marine UAS Summer School. Lisbon, Portugal. Title of the lecture: "Seafloor exploration and characterization using vision".
- 2017: Invited talk at the Faculty of Electrical Engineering and Computing of the University of Zagreb (Croatia). Title of the talk: "High-resolution Sea-floor Optical Mapping using Unmanned Underwater Vehicles".
- 2017: Invited talk at the Facultad de Ciencias del Mar de la Universidade de Vigo. Title of the talk: "Desarrollo de Tecnología al Servicio de la Exploración Submarina".
- 2016: Invited talk at the ICRA 2016 Workshop on Marine Robot Localization and Navigation. Stockholm, Sweden. Title of the talk: "Challenges for underwater perception and mapping using computer vision".
- 2015: Invited talk at the 6th International Workshop on Computer Vision in Vehicle Technology, in conjunction with IEEE Conference on Computer Vision and Pattern Recognition (CVPR). Boston, USA. Title of the talk: "Vision-based Robots to Explore the Ocean".
- 2015: Invited speaker at the 4th EOS Topical Meeting on Blue Photonics® - Optics in the Sea (Blue Photonics 4). Barcelona, Spain. Title of the talk: "High-Resolution Optical Seafloor Mapping and Characterization".
- 2015: Invited talk at the Faculty of Technology of the University of Bielefeld, Germany. Title of the talk: "Underwater Robot for High-Resolution Optical Seafloor Mapping and Characterization".
- 2014: Plenary Keynote Speaker at the Marine Imaging Workshop, National Oceanographic Centre Southampton, U.K. Title of the talk: "Underwater imaging: from nice evidence to useful data".
- 2014: Plenary Keynote Speaker at the International Symposium on Naval Architecture and Maritime INT-NAM, Istanbul, Turkey. Conference "3-D Mapping for the Characterization of the Seafloor using an Underwater Robot".
- 2013: Plenary Keynote Speaker at the Hispano-Brazilian Workshop on Autonomous Robots and Robotic Intelligence, Cáceres, Spain. Conference: "Underwater Robot for Autonomous Mapping and Intervention".

- 2013: Invited Talk “Techniques and Tools for High-Resolution Seafloor Mapping using Underwater Robots” at the University of Qatar, Doha, Qatar. Invited by the Qatar National Research Fund.
- 2013: Plenary Keynote Speaker at the Symposia on Automation and Computation for Naval, Offshore and Subsea Industry (NAVCOMP’2013), Rio Grande do Sul, Brasil. Conference: “Future trends in high-resolution benthic habitat mapping using autonomous underwater robots”.
- 2012: Plenary Keynote Speaker at the Jornadas Argentinas de Robótica (JAR’2012), Olavarria, Argentina. Conference: “Underwater Robotics as a key tool for Seafloor Exploration”
- 2012: Plenary Keynote Speaker at the IFAC Workshop on Navigation, Guidance and Control of Underwater Vehicles (NGCUV’2012), Porto. Conference: “Challenges and Limitations of High-resolution Sea-floor Optical Mapping using UUVs”.

Publications

Author or co-author of 56 journal articles, 3 books, 11 book chapters and more than 90 papers in peer-review conferences.

See <http://eia.udg.edu/~rafa/> for a complete list.

Books

- T. Nicosevici and R. Garcia. "Efficient 3D Scene Modeling and Mosaicing", Springer, 2013. ISBN 978-3-642-36417-4
- R. Prados, R. Garcia, L. Neumann. "Image Blending Techniques and their Application in Underwater Mosaicing", Springer, 2014. ISBN 978-3-319-05557-2
- A. Elibol, N. Gracias and R. Garcia. "Efficient Topology Estimation for Large Scale Optical Mapping", Springer, 2012. ISBN 978-3-642-30312-8

Selected Publications

- H. Rajani, N. Gracias, R. Garcia. "A Convolutional Vision Transformer for Semantic Segmentation of Side-Scan Sonar Data" (2023), Ocean Engineering, vol. 286, Part 2. ISSN 0029-8018. DOI: 10.1016/j.oceaneng.2023.115647.
- F. Ruscio, R. Costanzi, N. Gracias, J. Quintana, R. García (2023). “Autonomous Boundary Inspection of Posidonia oceanica Meadows using an Underwater Robot”, Ocean Engineering, vol. 283, DOI: 10.1016/j.oceaneng.2023.114988. ISSN 0029-8018.
- V. Franchi, H. Rajani, R. Garcia, B. Martinez-Clavel, N. Gracias (2023) Distortion Correction of AUV-acquired Side-Scan Sonar Data, OCEANS 2023 Limerick.
- E. Ochoa, N. Gracias, K. Istenic, J. Bosch, P. Cieslak, R. Garcia (2022) “Collision Detection and Avoidance for Underwater Vehicles Using Omnidirectional Vision.” Sensors, 22, 5354. DOI: 10.3390/s22145354
- R. Campos, J. Quintana, R. Garcia, T. Schmitt, G. Spoelstra, D. Schaap (2020). Modern 3D simplification methods and large scale terrain tiling. Remote Sensing, 12(3), 437. DOI: 10.3390/rs12030437
- K. Istenic, N. Gracias, A. Arnaubec, J. Escartin, R. Garcia (2020). Automatic scale estimation of structure from motion based 3D models using laser scalers in underwater scenarios. ISPRS Journal of Photogrammetry and Remote Sensing 159, pp. 13-25. DOI: 10.1016/j.isprsjprs.2019.10.007
- K. Istenic, N. Gracias, A. Arnaubec, J. Escartin, R. Garcia (2019). Scale Accuracy Evaluation of image Based 3D Reconstruction Strategies using Laser Photogrammetry. Remote Sensing. 11(18), 2093. DOI: 10.3390/rs11182093
- J. Bosch, K. Istenic, N. Gracias, R. Garcia, P. Ridao (2019). Omnidirectional Multi-Camera Video Stitching using Depth Maps. IEEE Journal of Oceanic Engineering. DOI: 10.1109/JOE.2019.2924276
- R. Garcia, R. Prados, J. Quintana, A. Tempelaar, N. Gracias, S. Rosen, H. Vågstøl and K. Løvall (2019). Automatic Segmentation of Fish using Deep Learning with Application to Fish Size Measurement. ICES Journal of Marine Science. DOI: 10.1093/icesjms/fsz186.

- R. Campos and R. Garcia (2018). Surface Meshing of Underwater Maps from Highly Defective Point Sets. *Journal of Field Robotics*, 35 (4), pp. 491-515. DOI: 10.1002/rob.21758
- K. Korotkov, J. Quintana, R. Campos, M.A.J. Silva, P. Iglesias, S. Puig, J. Malvey, R. Garcia (2018). An Improved Skin Lesion Matching Scheme in Total Body Photography. *IEEE Journal of Biomedical and Health Informatics*. DOI: 10.1109/JBHI.2018.2855409
- R. Campos, R. Garcia, P. Alliez, M. Yvinec. "A Surface Reconstruction Method for In-Detail Underwater 3D Optical Mapping". *The International Journal of Robotics Research*, vol. 34 no. 1 64-89, January 2015.
- K. Korotkov, J. Quintana, S. Puig, J. Malvey, R. Garcia. "A New Total Body Scanning System for Automatic Change Detection in Multiple Pigmented Skin Lesions". *IEEE Transactions on Medical Imaging*, vol.34, no.1, pp.317-338, 2015.
- R. Campos, R. Garcia, P. Alliez, M. Yvinec. "Splats-based Surface Reconstruction from Defect-Laden Point Sets", *Graphical Models*. Vol. 75, no. 6, pp. 346-361, 2013. ISSN: 1524-0703. DOI: 10.1016/j.gmod.2013.08.001
- T. Nicosevici, R. Garcia. "Automatic Visual Bag-of-Words for Online Robot Navigation and Mapping," *IEEE Transactions on Robotics*, vol. 28, no. 4, pp. 886-898, 2012. ISSN: 1552-3098. doi:10.1109/TRO.2012.2192013
- R. Prados, R. Garcia, N. Gracias, J. Escartín, L. Neumann. "A Novel Blending Technique for Underwater Giga-Mosaicing," *IEEE Journal of Oceanic Engineering*, vol. 37, no. 4, pp. 626-644, 2012. ISSN 0364-9059. doi: 10.1109/JOE.2012.2204152
- A. Elibol, R. Garcia, N. Gracias. "A New Global Alignment Approach for Underwater Optical Mapping," *Ocean Engineering*, vol. 38, no. 10, pp. 1207-1219, 2011. ISSN: 0029-8018. DOI:10.1016/j.oceaneng.2011.05.013
- J. Ferrer, R. Garcia. "Bias Reduction for Stereo Triangulation," *Electronics Letters*, vol. 46, no. 25, pp. 1665-1666, 2010.
- A. Elibol, N. Gracias, R. Garcia. "Augmented State-Extended Kalman Filter Combined Framework for Topology Estimation in Large Area Underwater Mapping," *Journal of Field Robotics*, vol. 27, no. 5, pp. 656-674, 2010.
- P. Ridao, M. Carreras, D. Ribas, R. Garcia. "Visual Inspection of Hydroelectric Dams using an AUV," *Journal of Field Robotics*, vol. 27, no. 6, pp. 759-778, 2010. ISSN: 1556-4959. DOI: 10.1002/rob.20351
- T. Nicosevici, N. Gracias, S. Negahdaripour, R. Garcia. "Efficient three-dimensional Scene Modeling and Mosaicing," *Journal of Field Robotics*, vol. 26, no. 10, pp. 759-788, 2009. ISSN (Print): 1556-4959. ISSN (Online): 1556-4967. DOI: 10.1002/rob.20305.

Final Exam: Multiple choice test

Room and Schedule

Room: *Aula Riunioni del Dipartimento di Ingegneria dell'Informazione, Via G. Caruso 16, Pisa – Ground Floor*

Schedule:

May 27, 2024: 14:00-17:00 (Lectures 1 and 2)

May 28, 2024: 14:00-16:00 (Lecture 3)

May 30, 2024: 14:00-16:00 (Lecture 4)

May 31, 2024: 14:00-15:00 (Lecture 5)