NSF – REU Project Description
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Correlation between Vector Field Features Embedded into Modified by Operators and Original Images

Vector fields (VFs) are characterized by features like singular points (SPs) and their patterns, index of SPs, trajectories, and separatrices. Using the Eigenvalues of the VF Jacobian, seven patterns can be defined in the vicinity of the SPs [1, 2, 3] of a complex valued VF. In recent years researchers from the artificial intelligence (AI), and Computer Vision (CV) societies explore the opportunities to employ the VF features for the purpose of automatic objects segmentation and classification [2-5]. To efficiently employ the VFs features for classification they should be invariant according to: small perturbations (in case of objects these are boundary jags or zigzags); affine transformation (scaling, translation and rotation); intensity, contrast and noise modification through logarithmic and exponential functions, equalization, gradient and Laplace operators. The present project will study the correlation between VF features of modified and original images.

Convolution is a fundamental Image Processing operation with scalars and is a basic component of Convolutional Neural Networks (CNNs). The students will study this operation and its use in the neural networks (NNs) . Upon time permission and/or students' interest we will work on the development of Vector Fields convolution.

Activities under the project:

a) basics of VF theory and features;
b) Some Machine Learning (ML) fundamentals;
c) Matlab software ELPAC that generates VFs on image objects. The software is developed by a faculty research group including master students and is published in [4], and [5].

The Student Researcher(s) will:

- learn a number of vector fields (VFs) with real and complex valued shapes of the SPs;
- study the VF features like singular points (SPs), separatrices and orbits as well as their correlation with objects geometric features;
- will find public image databases, will modify them with operators and will embed VFs with the ELPAC software;
- study the way jags, logarithmic, exponential, and equalization functions, as well as Gradient and Laplace operators modify the VFs and their SPs;
- study the opportunity for using the SPs by ML methods to enhance classification.

The project(s) listed above will require a stable knowledge in Calculus and Matlab, programing skills in Python would be of help and may replace Matlab.

References:

[1] Zhang, E., Mischaikow, K., Turk, G.: Vector _field design on surfaces. ACM Trans. Graph. 25(4), 1294{1326 (2006)

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[3] M. Chen, N. M. Sirakov. Poisson Equation Solution and its Gradient Vector Field to Geometric Features Detection. vol. 11324, pp. 1{13. Springer, Cham (2018)

[4] A. Bowden, N.M. Sirakov. Active Contour Directed by the Poisson Gradient Vector Field and Edge Tracking, Journal of Mathematical Imaging and Vision. Springer, IF 1.76 2020, SCR, published https://rdcu.be/caI

[5] N. M. Sirakov, A. Bowden, M. Chen, L.H. Ngo, M. Luong, "Poisson Gradient Vector Fields Features for Efficient Image Classification," J. of Computational and Applied Mathematics, Elsevier, IF 2.4, JCR 2021, *Published online November 20, 2023*
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