Computational Intelligence Re-meets Medical Image Processing

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The recent rapid advances in medical imaging and automated image analysis allow us to make significant improvements in our understanding of life and disease processes, and our ability to deliver high-quality healthcare.

Medical imaging and the image processing domains mainly manage and process missing, ambiguous, inconsistent, complementary, contradictory, redundant, and distorted data, and information has a strong structural character. In general, the processes of human and artificial understanding of any image involve the matching of features extracted from the current image with prestored models. From the information technology point of view, the production of a high-level symbolic model requires the representation of knowledge about the objects to be modeled, their relationships, and how and when to use the information stored within the model. Therefore, all traditional and advanced techniques of image processing and computer vision, analysis, and understanding may be used to process medical images, to extract useful information for diagnosis, treatment, and prevention.

A special approach, which represents the editors' proposal for this focus theme, directs to the use of artificial intelligence and computer vision, which recently have proven to yield promising results in medical image processing and analysis. This is because the structural character of information may be approached successfully by several of these methods. For instance, data fusion solves the aggregation of numerical and linguistic information and is able to cope with often defective information, like that occurring in the biomedical imaging domain.

With continuing evolutionary progress in biomedical imaging, visualization, and analysis, we can fully expect to benefit from new knowledge about life and disease processes, and from new and efficient methods of diagnosis, therapy, and prevention.

This Focus Theme presents new paradigms and prominent applications in biomedical image processing, in direct relation with latest concepts in computational intelligence and computer vision. A call for papers was issued for manuscripts falling into the following main areas of the artificial intelligence:

- Deep and Reinforcement Learning.
- (Convolutional) Neural Networks.
- Fuzzy Logic and Systems, Neuro-Fuzzy Systems & Rough Sets.
- Evolutionary and Bio-Inspired Algorithms.
- Intelligent, Deformable Models.
- Symbolic Calculus for Knowledge Representation.
- Knowledge Based Systems.
- Decision Support Systems (Computer-Aided Diagnosis).
- Data Mining & Knowledge Discovery.
- Semantic Nets & Data Fusion.

Original and high-quality papers reflecting the above concepts and methods were rigorously reviewed by at least three reviewers. Thus, the two selected papers reflect innovative and novel studies showing interesting and useful results and interpretations in intelligent biomedical image processing.

The first article, “Analysis of Machine Learning Algorithms for Diagnosis of Diffuse Lung Diseases,”[1] authored by a multinational research group led by Prof. Rangaraj M. Rangayyan, from the University of Calgary, Canada, refers to a computer-aided diagnosis application related to diffuse lung diseases, which are dangerous chronic disorders of the respiratory system with a difficult diagnosis process.[2] The article reflects a thorough study and shows that the diagnostic accuracy is significantly improved by an intelligent image analysis carrying out both at the features level and classification stage. Principal component analysis, linear discriminant analysis (LDA), and stepwise selection were used to reduce feature dimensionality. The feature subsets obtained were used as input to the following powerful machine learning methods: support vector machine,[3] Gaussian mixture model,[4] k-nearest neighbor, and deep feedforward neural network (DFNN).[5] The authors also applied a deep convolutional neural network[6] directly to the selected regions of interest. As a result, they achieved a significant reduction of feature dimensionality

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from 28 to 5 dimensions using LDA. The best classification results were obtained by DFNN, with 99.60% of overall accuracy, which is a remarkable outcome.

The second article[7] describes an interesting application of bio-inspired algorithms for image registration, and is entitled "A Comparison of Some Nature-Inspired Optimization Metaheuristics Applied in Biomedical Image Registration." It is authored by Silviu-I. Bejinariu and Hariton Costin, from the Institute of Computer Science, Romanian Academy Iasi Branch, and the University of Medicine and Pharmacy, Iaşi, Romania, respectively.

Because many image-processing procedures, from low level to high level, imply different methods viewed as optimization problems, nature- or bio-inspired metaheuristic algorithms were developed in the last decades as new optimization methods based on the nature's intelligence.[8] These metaheuristics can find a nearly optimal and global solution faster than other traditional algorithms even for high-dimensional optimization problems. In general, they use memory, solution history, and other forms of "learning strategy." They have the following features[9]:

- capability of finding the true global optimality and escape from local minima;
- no need of domain-specific knowledge;
- treatment of problems as a black-box;
- dealing with highly nonlinear, multimodal and discontinuous problems;
- generally gradient-free methods;
- stochastic components in terms of random numbers and random walks;
- powerful and efficient for solving several classes of NP-hard real-world problems.

In the presented study, a set of three nature-inspired algorithms, that is, Cuckoo search algorithm (CSA),[10] particle swarm optimization (PSO),[11] and multi-swarm optimization (MSO),[12] are compared in terms of strategies used in the evolutionary process and also regarding the results obtained when applied for multimodal biomedical image registration. The objective of this research is to identify the most reliable optimization algorithm for this class of problems. The criteria taken into consideration are not only the precision of the results and convergence speed, but also the required computing resources.

For image registration, a geometric transform required to obtain a perfect overlay of two or more images.[13] The images have been acquired using the same or different sensors, from different viewpoints or at different times. One of these images is considered as model and for all the other images (sources) a geometric transform has to be computed, so that when it is applied to the source, the result is aligned to the model image.

The results were obtained by using two data sets taken from the freely available OsiriX database with Digital Imaging and Communications in Medicine medical images.[14] These results revealed that (1) PSO offers the most precise solutions, (2) CSA and MSO are more stable in the sense that their solutions are less scattered, and (3) MSO and PSO have a higher convergence speed. As a conclusion, the nature-inspired algorithms demonstrated their efficacy for image registration. So in conclusion, computational intelligence is not only deep learning but means also other methods, and deep learning in medical image processing is not only CNN but also other network architectures. There are a variety of powerful methods of computational intelligence. However, there is still the need to carefully select the appropriate methods that best fits a certain problem, and a general rule guiding the scientists here is not known (yet).

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