

Guest Editorial: AI Enabled Connected Health Informatics

I. INTRODUCTION

TODAY, on one hand, software frameworks for deep learning are becoming increasingly capable of training advanced neural-network models, while on the other hand, heterogeneous hardware components such as GPUs, FPGAs and ASICs dedicated to deep learning are beginning to challenge the computational limits of Moore's law. Together, these trends have influenced connected health systems, which comprise various processes for sensing, data transfer, storage and informatics to improve overall health and wellbeing. Increasingly, each of these processes are being infused with artificial intelligence (AI), leading to unprecedented advances in how automated care is being delivered. The purpose of this Special Issue is to capture some of the advances in AI when applied to health informatics. There are nine papers covering the areas of medical imaging informatics (3 papers), interpretable models (2 papers), cloud-assisted analytics (2 papers) and gait informatics (2 papers).

II. A BRIEF OVERVIEW OF THE PAPERS IN THIS SPECIAL ISSUE

A. Medical Imaging Informatics

There are three papers that focus on imaging informatics targeting data from MRI and CT scans. The first one by Trivizakis *et al.* tackles the problem of tissue classification in medical images to discriminate between primary and metastatic liver tumors from Diffusion Weighted MRI (DW-MRI) data. The authors propose a 3D convolutional neural network (CNN) to achieve this goal. They evaluate their model on 130 DW-MRI scans. This end-to-end approach achieves a significant improvement in classification performance (of 83%) compared to an approach based on analyzing 2D images (69.6%). The significant improvement in classification accuracy can be attributed to multiple factors including better image representation, voxel kernels, network architecture and better features.

The second paper by Abdolmanafi *et al.* aims to accurately register multiple images from Optical Coherence Tomography (OCT), which is important to analyze volume variations and pathological formations in the heart. 3D assessment of the morphological tissues is problematic because they are highly affected by motion artifacts resulted by the rotation and translation of the imaging catheter along the artery during image acquisition. Generally, heart beating and respiration during OCT acquisition are the main sources of both axial

and longitudinal motions. In this paper, the authors apply deep learning on intracoronary OCT images for motion correction for the first time. They correct intra-slice motion in intravascular OCT images using tissue information rather than the lumen outline. In fact, the proposed approach has broader applicability beyond OCT motion correction, including the evaluation of different plaque formations and tissue deformations.

In the third paper, Du *et al.* propose an end-to-end deep learning model for holonomic quantitative analysis of the left ventricle. More specifically, they extract contours of the ventricle via a deep convolutional encoder-decoder model. Then, they process the predicted contour with a second neural network model for full quantification. The key idea is that the authors exploit inter-relationships between different tasks to achieve highly accurate cardiac image segmentation, which is beneficial for comprehensive clinical assessment and diagnosis. They have conducted experiments on MR sequences of 145 subjects and demonstrate segmentation errors under 157 mm², 2.43 mm, 1.29 mm and 87 on areas, dimensions, regional wall thicknesses (RWTs), and Dice Metric (DM), respectively.

B. Interpretable AI Models

It is true that many AI-based approaches to healthcare are criticized for being black-box methods. Therefore, it is important to develop AI methods that can attribute specific characteristics to clinically-indicative parameters. This section brings together two papers that aim to increase the interpretability of AI that is used in medical informatics.

In the first paper by Colopy *et al.* the authors consider challenges in a Step-Down Unit (SDU). Current methods for clinical monitoring within SDUs are largely based on heuristics, requiring manual calculation of risk scores and the use of heuristic decision criteria. They also ignore time-series dynamics of physiological measurements, and lack patient specificity. The authors demonstrate the benefit of Gaussian process regression (GPR) models. They show that GPR models can be used to supplement current monitoring practice by providing interpretable and intuitive illustrations of erratic vital-sign volatility. Thus, they develop an approach that can pinpoint the cause of alarms generated in SDUs. Their models are also explicitly interpretable and intuitive.

In the second paper, Sahu *et al.* propose to automatically analyze CT scans. Their approach is in contrast with previous approaches that employ computationally-intensive deep ensemble models or 3D CNN models. The authors propose a lightweight multi-view sampling-based multi-section CNN.

Thus, their approach leads to compact features that encode aggregated information from different cross-sections enabling accurate nodule classification downstream. The proposed method was evaluated on the LIDC-IDRI dataset and was found to achieve state-of-the-art performance with a mean classification accuracy of 93.18%. The model is not only accurate but also interpretable, due to the ability of selective cross-sectioning, and portable because of low-computational complexity.

C. Cloud-Assisted Analytics

Cloud-assisted Analytics is an important piece in the AI-history not only for serving pre-trained models in real-time but also for providing a distributed infrastructure where complex models can be trained fast. This SI brings together two papers that emphasize the role of the cloud in modern AI-enabled connected health systems.

The first paper aims to increase the ability to access, compare or reuse deep-learning methods by clinicians. Milletari *et al.* have developed TOMAAT, which is a unified open-source cloud framework to provide AI-enabled medical image analysis. It provides services exposed via an HTTP API, distributed server nodes and client software necessary for image manipulation and analysis. They have demonstrated the benefit of TOMAAT for image segmentation, diffeomorphic deformable atlas registration, landmark localization and workflow integration. The provided software thus fosters interaction among deep learning researchers and medical collaborators. TOMAAT is currently hosted by the authors and several ready-to-use services are enlisted.

In the second paper, van Wyk *et al.* present a novel method for hierarchical analysis of machine learning algorithms to improve predictions of at-risk patients, which further enables prompt therapy. Their approach uses a hierarchical classifier and moving-time windows that explicitly account for past temporal changes in time-series data to improve prediction performance. The authors use sepsis prediction as a case study. Sepsis is a major cause of mortality around the world, and its treatment cost is one of the highest among several medical conditions. Unlike traditional cascading classifiers, the authors develop their multi-layer models to operate in real-time using continuous features generated from the previous models. This approach allows for real-time analysis of both coarse and subtle changes in the time series data, providing an opportunity for detecting the hidden patterns. They evaluate their methods on a cohort of patients and data were collected under controlled settings. They show that processing the output of a first model using another machine learning model, instead of an a priori threshold, can improve the overall performance with respect to F2 score.

D. Gait Informatics

AI has been applied extensively to analyze human gait. There are two papers in this SI that tackle this important problem. The first paper addresses the growing need to increase the data security of miniaturized wireless health devices. Sun *et al.* extract gait-based signatures to provide a biometric cryptosystem that aims to achieve this goal. They propose a novel gait-based

security scheme with ANN for securing wireless communications for wearable and implantable healthcare devices. The key idea is that by simultaneously extracting features from various sensors on the body, binary keys can be generated on demand without user invention. These keys have high entropy and can pass both National Institute of Standards and Technology (NIST) and Dieharder statistical tests with high efficiency. The authors demonstrate that the probability of a successful intra-class fuzzy key exchange using the BCH pair (127, 8, 31) within 4 attempts for all sensor positions can reach 95%, and inter-class keys possess the property of high distinctiveness, with a mean Hamming Distance of 49.96% for 15 subjects. Their experimental results demonstrate the feasibility and robustness of the proposed security scheme and its resilience against common attacks.

In the second paper, Li *et al.* go beyond conventional activity recommendations from fitness trackers and smartphone applications. They develop an approach for providing data-driven and personalized recommendations for intraday activity planning. They generate an hour-by-hour activity plan that is based on the user's probability of adhering to the plan. They also create an alerting mechanism that is specifically tailored to individuals. Their approach relies on abundant physical-activity data collected from a large population of fitness trackers. Their application runs on a smartphone and the calculations needed to generate the adaptive activity plan occur hourly by considering the user's steps for the past hours in the same day. In addition, cleverly devised online-offline arbitration mechanisms enable low-power operation that is critical to the adoption of such a system.

III. CONCLUDING REMARKS

The papers presented in this Special Issue provide a snapshot of the latest research advancements in all aspects of connected health and informatic systems where AI has been evident, including sensing, transfer, storage and analytics of biomedical data. This Special Issue captures the end-to-end view of solutions that use automated informatics to address single or multiple scenarios of health engineering such as primary care, preventive care, predictive technologies, hospitalization, home care, and occupational health.

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