Artificial Neural Networks in Medicine: Recent Advances

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Steven Walczak
https://orcid.org/0000-0002-0449-6272
University of South Florida, USA

INTRODUCTION

Medicine is a field closely coupled with and producing big data (Najafabadi et al., 2015), especially with the growing adoption of electronic health records (EHRs) in the United States (Bourgeois & Yaylacicegi, 2010; Mennemeyer et al., 2016) and the world (Wager et al., 2013, Appendix C). Medical big data serves as a critical resource for medical research and clinical decision making. Artificial neural networks (ANNs), along with other machine learning approaches, have been shown to be an effective method for analyzing medical big data to develop diagnostic and prognostic systems (Pastur-Romay et al., 2016).

Although ANNs have a short history of application in the field of medicine, with the first published research appearing in 1990 (Asada et al., 1990; Baxt, 1990; Dassen et al., 1990), there has been a continuing and growing trend of research investigating ANNs in medicine. Interestingly, two of the three articles published in 1990 were published in medical journals, while only Baxt's (1990) article on diagnosing heart attacks (myocardial infarctions) was published in an information technology journal, but he followed this work up with multiple publications in medical journals (Baxt, 1991, 1992). Searching the National Library of Medicine PubMed database for articles containing the term "artificial neural network" combined with any of the terms: medicine, medical, hospital, patient, diagnosis, prognosis, clinic, or pharma (https://www.ncbi.nlm.nih.gov/pubmed/?term="artificial+neural+network"+AND+(medicine+OR+medical+OR+hospital+OR+patient+OR+diagnosis+OR+prognosis+OR+clinic+OR+pharma)) produces the results shown in Figure 1, which displays the annual increase in articles focusing on ANNs in medicine.

The amount of ANN in medicine research is even greater than depicted in Figure 1, since terms like "deep learning neural network" or "convolution network" or "evolutionary network," which are all types of ANN, are not included. Other researchers have also indicated a larger quantity of ANN research in medicine, with 473 articles in 1998 (Dybowski, 2000) as opposed to the 66 articles identified with the more specific search criteria. Other research claims an earlier start date, 1981, for the beginning of ANN usage in medical decision support (Miller, 1994), but here we report only those articles listed in the PubMed database.

ANN research in medicine is used to develop models and systems for a variety of applications including: decision support systems for both patients and surgeons, diagnosis, prognosis, resource planning and allocation, and variable significance and protocol heuristic evaluation. The goal of any research in the field of medicine should primarily be to improve the quality of life of the patient and secondarily to promote workflow efficiencies and cost reductions.

Next a brief definition of ANNs and a short historical perspective is presented. The purpose of this article is not to instruct researchers in how to develop an ANN, but rather to examine recent trends and

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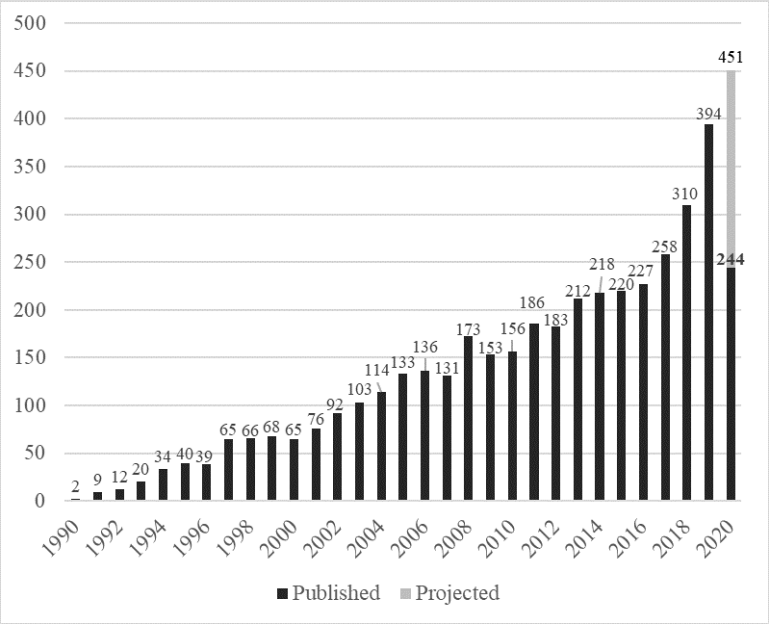
Figure 1. Medline/PubMed ANN articles in medicine as of July 15, 2020



advances in ANN research in medicine. Readers interested in a more general introduction to ANNs should examine the readings listed in the Additional Readings section. After the brief definition and historical background, recent research is described and trends in applying ANNs in medicine are discussed. Finally, future research directions are presented.

BACKGROUND

Artificial neural networks (ANNs) are a machine learning based classification and forecasting tool, based on modeling the neuronal activity of the human brain. ANNs come in a variety of architectures, which are represented by a large collection of interconnected processing elements called neurodes, and utilize a wide range of machine learning algorithms. These algorithms may be classified as either unsupervised learning or supervised learning or hybrid learning algorithms that utilize both unsupervised and supervised features.

Unsupervised ANNs learn classifications directly from the data they are analyzing and have long been used for image analysis in medicine, including mammography (Floyd Jr. et al., 1994; Leinsinger et al., 2006), MRI (Amartur et al., 1992; Wismüller et al., 2004), and other images (Jiang et al., 2010; Lin et al., 1996). Newer deep learning unsupervised ANNs are still being used for image classification and diagnosis based on images (Kallenberg et al., 2016).

Supervised ANNs require data with known outcomes to help guide the machine learning algorithms used in ANNs. Retrospective medical data is readily available from EHRs and other medical databases to serve as training data for supervised learning methods. Supervised learning ANNs have their neurodes arranged in layers, with increasing numbers of hidden layers enabling a higher degree of nonlinearity in the resultant model (Walczak & Cerpa, 1999).