Deep learning applications in biomedical engineering - summary

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In the early days, artificial intelligence algorithms were mainly constructed using the so-called *expert systems*. These were the algorithms that most often implemented an inference system based on fuzzy logic. Fuzzy logic is a framework in which logic operations are applied to continuous variables that represent the membership of a given feature in a given category. To create a fuzzy inference system for a given problem, the computer scientists must first create a *knowledge base* - its a construct that represents the in-domain knowledge about the phenomenon studied. Based on the knowledge base, scientists can construct a set of rules that describe the input-output relationship of the considered features and their respective classes. Expert systems are often described as transparent, easy to implement, work with, and adjustable. But they are also single purpose, costly to develop, do not provide new knowledge, and require the following steps:

- creation of a knowledge base - collecting the necessary information to solve a problem,
- creation of a feature extraction pipeline - selecting relevant features (from image, audio, etc.) that will be useful for the fuzzy inference system,
- creation of a fuzzy inference system.

Machine learning is an alternative approach to artificial intelligence in comparison to expert systems. It revolves around the idea that the data itself, in its annotated form, provide enough information to create a statistical model capable of mapping the input features to relevant categories through some optimization process. To create a machine learning system, you must do the following steps:

- provide collection of labeled examples to a given problem,
- create a feature extraction pipeline,
- select the algorithm - this step automates the decision making process.

Deep learning goes one step further, instead of creating a feature extraction pipeline, it tries to optimize its set of parameters to actively select the relevant features needed to make an accurate prediction. By allowing an algorithm to choose the relevant features, we abandon the transparency of algorithms such as fuzzy inference expert systems in exchange for automating the feature extraction and the decision-making process. This approach has led to a revolution in many computer science fields and can be also utilized for biomedical and life sciences applications (which this dissertation describes), such as:

1. Predicting Molecule Toxicity Using Deep Learning,
2. Recognition of Drivers' Activity Based on 1D Convolutional Neural Network,
3. Heartbeat Detection in Seismocardiograms with Semantic Segmentation,
4. Semantic Segmentation of 12-Lead ECG Using 1D Residual U-Net with Squeeze-Excitation Blocks.

Furthermore, this dissertation also outlines the main problems that these algorithms face when applied in the medical domain. The biggest being the transparency problem. Although powerful, these deep neural networks do not provide a sufficient explanation for their decision-making process, which in turn is crucial when considering their applicability to any healthcare applications. Because of that, this dissertation introduces a new concept called *fuzzy representation learning* which combines the advantages provided by neural networks and a fuzzy inference system. It is a new type of algorithm, in which the neural network, through the optimization process, tries to create the entire, fuzzy inference system that solves a given problem, just based on the example training set.