Paper Review of Gary Marcus' Deep Learning: A Critical Appraisal

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Deep Learning has been the buzzword in the past decade and rapid developments in this field has augmented this trend. But does deep learning have no shortcomings? Is it really the panacea that it was envisaged? Can these models achieve human-level intelligence? These are some of the questions addressed in the 2017 paper "Deep Learning: A Critical Appraisal" by Gary Marcus. He analyzes the limitations of the then prevailing deep learning advancements. Furthermore, he also suggests new paradigms for AI research.

Gary Marcus apprehends that despite deep learning models being successful in a wide range of domains including image detection and classification, speech recognition, game playing, etc.; it seems to have encountered a wall. He discusses some of the major challenges that today's deep learning models face. One issue of DeepNets is regarding the models being very data-hungry. This is indeed a valid problem but we must understand that DeepNets don't have a prior unlike humans (who do transfer learning from other tasks) so they require bigger datasets as they learn from the very beginning. But there has been significant progress in the field of one-shot and few-shot learning in the recent years but their applications might still be limited. Learning through a curriculum has also been an area of research (inspired from how a child learns). He also points out that DeepNets are shallow and have limited 'transferability'. Neuro-Symbolic Concept Learning is a new sub-domain which is making neural models learn concepts (as neural operators) and is an exciting area of research. VQA (Visual Question Answering) is a task which is commonly realized through these concept learners. Applications are still limited but there is a large scope for improvement. He also mentions that DeepNets don't handle structure, inference and causality very well especially pertaining to human language comprehension. This is quite valid as neural networks can handle correlations very well but causality is something which classical AI (especially reinforcement learning in the Bayesian context) manoeuvred well. Neural networks currently can generate sentences but don't have a sense of the semantics associated with it. His points about DeepNets not being transparent and failing to incorporate prior knowledge are somewhat addressed through the advent of explainable AI (XAI in neural networks context) and knowledge-based neural networks. They try to explain abstract representations in the intermediate latent states so that we get a sense of the purpose of each layer of DeepNets. Knowledge bases and graphs can be incorporated through knowledge-based networks and graph convolutions.

In order to address these issues with DeepNets, he proposes some new directions of research. He is in the favour of deep learning in an unsupervised setting that alleviates data-hungriness. Fortunately, significant progress has already been made in this direction with GANs (Generative Adversarial Network) being the torch-bearers. He is also a proponent of integrating symbolic AI with DeepNets. In addition, this is a domain where progress has been made with Neuro-Symbolic AI playing a significant role. Furthermore, he points at human cognition as a potential direction. Insights into human mind and perception will certainly bolster AI research.

All-in-all, it was a paper regarding the limitations of deep learning and had a lot of valid points though some of the points have already been addressed by current state-of-art. It has been 3 years since this paper was published and we do see results in the directions referred in the paper. Combining classical AI (symbolic AI) and deep learning has yielded good results. Neuro-Symbolic Reasoning touted as the 3rd wave of AI has achieved unprecedented impact across research communities and industries. Incorporating insights from cognitive science has been fruitful. Deep Networks can now learn cognitive models that can interact with its environment and help humans make better decisions.