MORGAN CREEK
DIGITAL
ALTERNATIVE THINKING ABOUT INVESTMENTS

*Welcome to Morgan Creek Digital's weekly digital asset update. It is comprised of a thought piece from our team followed by a summary of what we consider the most compelling digital asset news during the last week. We hope you find this content interesting. Please let us know if you have any comments or questions or if you would like to speak to a member of the Morgan Creek Digital team.*

Dear Readers,

Artificial Intelligence has once again piqued the curiosity of technology enthusiasts. In this current hype cycle, OpenAI's chatbot, ChatGPT, has acted as the catalyst for renewed excitement and, in many cases, fantastical imagination. In this newsletter, we would like to look "under the hood" and discuss the technological advancement, **backpropagation**, and how it has enabled modern neural networks.

Artificial Intelligence ("AI") applications, like ChatGPT, can comb through and process data to predict words and phrases given a seed phrase or human-generated input. The seed phrase is vital because semantic models have no agenda or communicative purpose other than making language associations. ChatGPT, built on top of OpenAI's GPT-3 family of large language models, recognizes patterns from surveying massive training sets of data, essentially the text within the internet, and replicates word and linguistic correlations.[1] While this chatbox and others can appear to have a conversation, it often forgets what was said earlier in the discussion, makes inconsistent arguments, and becomes caught in loops because machine-learning models lack flexible concepts. For example, let us look at a model designed to edit an essay (i.e. Grammarly). While the tool can be beneficial for scoring essays by scanning for words, phrases, and grammar typically used in other high-scoring essays, it cannot follow arguments or the logical flow of points. Semantic models are not good at reasoning, constructing, or dissecting arguments; instead, they search for language that may plausibly fit or correlate with a given context.[2]

**Backpropagation, what is it?**

The specific algorithm architecture developers of modern neural networks use for training is a technique called backpropagation, which employs the chain rule to pass data through extensive neural networks with many connections.

**Let's Geek out for a moment**:
The chain rule is a fundamental rule in calculus that allows us to differentiate composite functions. [3] It states that if a function f(x) can be expressed as the composition of two functions g(x) and h(x), i.e., f(x) = g(h(x)), then the derivative of f(x) for x is given by the product of the derivatives of g(x) for h(x) and the derivatives of h(x) for x. Mathematically, the concept is written as:

$$d f(x) / d x = d g(h(x)) / d x = d g(h(x)) / d h(x) * d h(x) / d x$$

Calculus relies on the chain rule because it enables us to calculate the derivatives of complex functions, which are often composed of simpler functions. Similarly, backpropagation efficiently adjusts its "weights" in neural networks based on the error between the predicted and actual outputs, computing an error gradient.[4] The error is then propagated backward through each layer of the network by calculating the partial derivative of the error with respect to the output of each node and then using the chain rule to compute the gradient of the error function with respect to the network's weights.

Stated more simply, backpropagation and advanced computational power have been instrumental in developing artificial neural networks and breakthroughs in various applications. The algorithm is repeated many times until the network predicts the output for a given input. This process allows these models to handle massive data sets by assigning credits to nodes in vast networks and recognizing complex relationships between inputs and outputs.[5]

Backpropagation, however, is an expensive algorithm, requiring significant computing power to train large neural networks. It is also susceptible to overfitting, which occurs when a model becomes too specialized to the training data and cannot generalize well to new and different data inputs.[6] Whereas the human brain consumes a fractional amount of data in its lifetime compared to AI, it can still form neural prototypes and construct abstract representations to make sense of new data inputs and form concepts that are activated or brought to recollection when needed to reason. The human mind can label data based on characteristics, properties, and classifications. If someone instructed you to think of a bird, your brain would likely form a prototype that conceptualizes features like wings, feathers, and flying, typically rendering an image most similar to a robin or sparrow. However, you still reserve the neural flexibility to label a non-traditional bird prototype, like a flamingo or penguin, as belonging to the category of birds. Backpropagation is a supervised learning algorithm requiring labeled data to train the model. In some cases, labeled data may not be available or may be expensive to obtain, limiting the application of backpropagation in real-world applications.

Backpropagation is a robust algorithm that has influenced the development of artificial intelligence. Researchers and builders are continuously exploring new technically advanced algorithms to overcome existing limitations and improve performance, which could create investment opportunities from Morgan Creek Digital's perspective. In the meantime, here are some considerations when evaluating an AI startup.

1. Is the founding team technically proficient?
2. How is the technology being built? Is it in-house, open sourced, or outsourced AI? While external technology may save on costs, companies not developing proprietary technology act more as service providers and absorb technical risks associated with building on top of non-proprietary models.
3. Where are the structured data sets retrieved from, and what is the error rate or limitations?

**Stay tuned as we dive deeper into AI applications and the potential opportunities it creates.**

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[1] https://openai.com/blog/chatgpt/

[2] https://www.forbes.com/sites/kalevleetaru/2019/01/15/why-machine-learning-needs-semantics-not-just-statistics

[3] https://machinelearningmastery.com/the-chain-rule-of-calculus-for-univariate-and-multivariate-functions

[4] https://deepai.org/machine-learning-glossary-and-terms/backpropagation

[5] https://deepai.org/machine-learning-glossary-and-terms/backpropagation

[6] https://machinelearningmastery.com/introduction-to-regularization-to-reduce-overfitting-and-improve-generalization-error/

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