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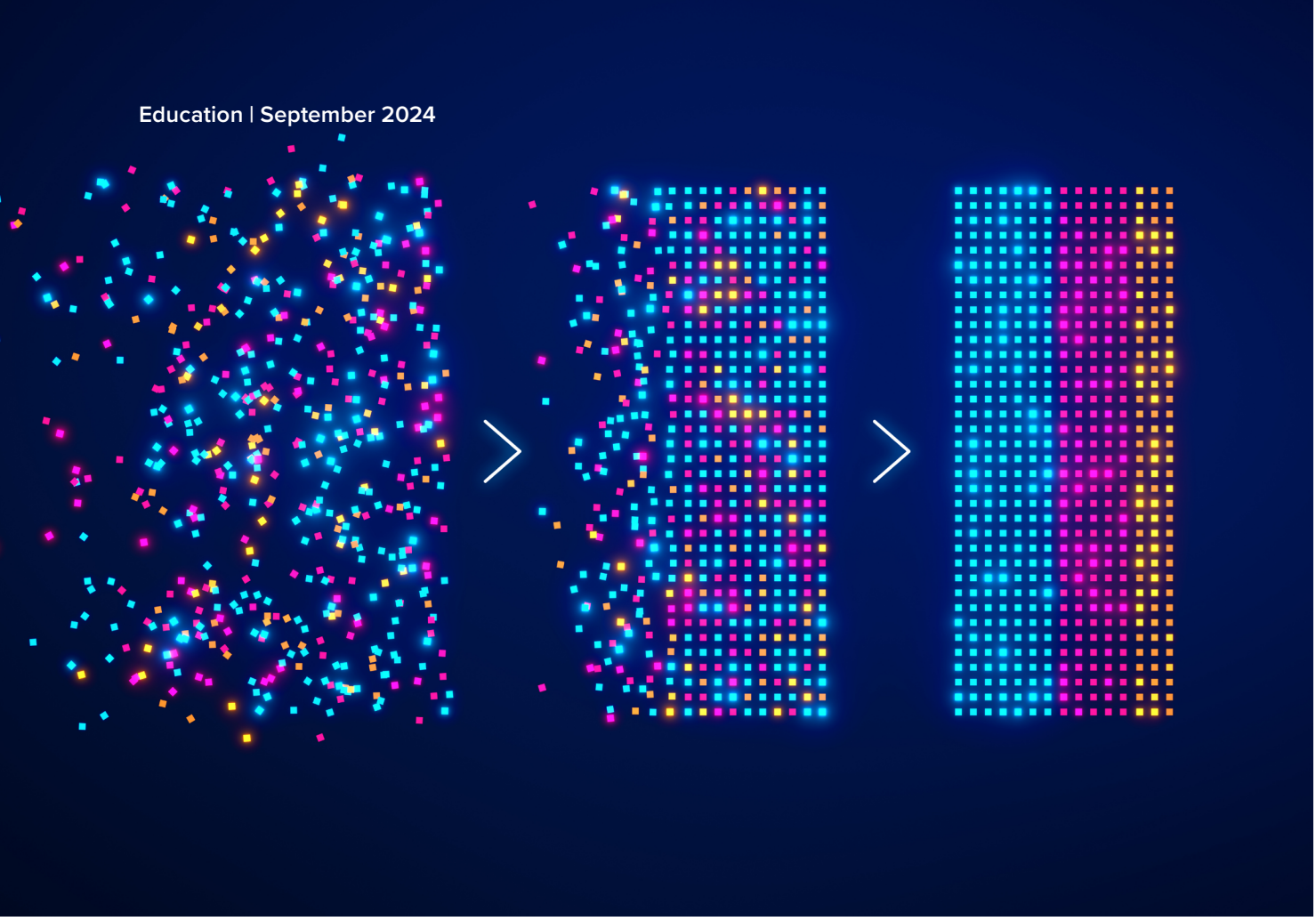

A Guide to Investing with Artificial Intelligence

The future of asset management is rapidly approaching—one in which the strengths of humans and machines are integrated to potentially make faster, better decisions. This guide is for allocators looking to understand how AI/ML models operate in an investment context, which ones are most effective in different situations, and how Voya approaches the complexities of practical implementation.

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Executive summary

As with any technological leap, the integration of machine-driven decision-making capabilities into investment strategies demands a heightened level of due diligence. As a former equity manager researcher, I've been through the process and I understand the daunting task that asset allocators face. Shorter live track records are inevitable when dealing with new technologies (and you'll never see a "bad" backtest). It's important to know how AI models function within an investment context and which ones are effective for different scenarios. And then there's the unavoidable issue of how to compare AI-driven strategies against established quantitative and fundamental strategies.

This guide is for investors seeking a better framework for assessing the merits of various approaches in this rapidly evolving field. We have structured the discussion around three key topics:

Applying AI models to investing

Effective investment strategies require a balanced use of human expertise and rational analysis alongside AI data-processing and problem-solving capabilities. Understanding the pros and cons of each is critical to identifying new ways for humans and machines to work together in investing.

Designing an AI investment framework

In a world of messy and limited information, successful AI integration starts with human domain experts curating data—helping to ensure diverse, high-value inputs—and providing some ground rules. Then it's a matter of matching the requirements and parameters of a specific investment task with the right combination of AI (and human) tools.

Defining best practices

Voya Machine Intelligence uses a "neuro-symbolic" process that relies on human skills for data preparation and feature engineering, and it taps machine capabilities for pattern recognition and conviction rankings. Grounded in the team's 10+ years of experience,[1] this framework has led to unique investment ideas and alpha generation in a cost-effective manner, thus raising the bar for both fundamental and quantitative managers.

[1] Inclusive of time at G Squared, acquired by Voya in 2020.

Applying AI models to investing

The idea behind machine-enhanced investment strategies is straightforward: Combine human expertise with AI's predictive powers to improve a manager's ability to seize opportunities and avoid mistakes.

Integrating these talents is like being a team leader, recognizing each contributor's strengths and weaknesses and putting them in a position to do their best work. The first step is to understand how humans and machines process and respond to information—in other words, how they "think."

Instinct (System 1)

- Fast
- Effortless
- Mysterious

Logic (System 2)

- Slow
- Deliberate
- Explainable

The power (and bias) of the human brain

The human brain has a 200,000-year head start on artificial intelligence. Over this period, we've developed two distinct thinking systems: instinct and logic. This idea might seem obvious now, but it was a groundbreaking concept in the late 1970s, when psychologists Daniel Kahneman and Amos Tversky first introduced it in terms of System 1 (fast) and System 2 (slow) thinking.

Instinct is an instant response that operates effortlessly in our subconscious, allowing us to carry out routine activities such as walking or recognizing familiar faces. Although we perform these tasks daily, their inner workings remain a mystery.

Logic, on the other hand, involves a conscious decision resulting from deliberate analysis and allows us to handle more complex tasks, such as solving math problems or making decisions in traffic. While more complex, logic can be explained, taught and (in theory) replicated.

Ideally, portfolio managers should balance both types of thinking—beginning with logic, which forms the foundation of a disciplined investment philosophy and process, and then layering in instinct.

For a skilled portfolio manager, instinct is that deep-rooted impulse, shaped by experience, that tells them when an opportunity is being overlooked or something seems off. However, instinct is susceptible to biases that can distort judgment. In practice, distinguishing instinct from emotions is challenging, sometimes leading to emotionally driven errors, such as clinging to a losing stock for too long or chasing performance. Indeed, one of the primary ways investors destroy value is through human irrationality.

From the allocator's perspective, it is possible to identify sound logic in the investment process, but it is much harder to ascertain the intuitive skill of a portfolio manager. This difficulty is one of the key reasons why quantitative strategies have gained in popularity—they remove emotional bias, relying purely on logic. However, quant investing has a major flaw: It lacks the ability to go as deep as a human in forming a holistic view of a company.

Can AI help humans overcome bias *and* avoid the limitations of traditional quantitative models? Yes, perhaps. But machines bring biases of their own.

Machine processes in investing

It is tempting when handed a shiny new toy not to expect too much from it. A key lesson when using machines for investing is understanding what a model can and can't (or shouldn't) do. Below, we describe some of the core architectures most relevant to investing and where they fit in the process.

AI type	What it does	Investment applications
Expert systems 	■ This subset of AI replicates complex decision-making processes using inputs from human experts within a specific, narrow field. ■ Known as deterministic or "rules-based" AI, these systems require an architect or developer to encode explicit instructions and decision trees. ■ This approach has been widely used to aid medical diagnoses, and it's the type of AI that beat chess champion Garry Kasparov in 1997.	■ Fundamental equity investing employs a complex set of rules and principles to analyze data and make predictions about future returns, aligning closely with the capabilities of both expert systems and machine learning. ■ Guided by features built using expert systems, ML algorithms can evaluate data to identify patterns and anomalies that may not be discernable or computable by the human brain. ■ These models can detect outliers in datasets to provide a clearer understanding of risks and potential opportunities. They can remove human biases, potentially elevating the investor's skill while reducing error to potentially deliver better results to clients. And they can evaluate a larger investment universe at a deeper level than traditional quant models, thus enhancing the potential for alpha generation and raising the bar for human and quant investors alike.
Machine learning 	■ Rather than requiring specific instructions, machines are trained on data to find patterns and make informed guesses through repeated trial and error, much like a human fundamental analyst. ■ Although machine learning systems still need human guidance, their ability to operate without rigid programming offers greater flexibility.	
Deep learning 	■ Deep learning is an advanced subset of machine learning that employs multiple layers of neural networks. ■ Trained on massive databases, these systems can process highly complex inputs to identify patterns with little to no human intervention.	■ Deep learning models excel in areas where data is bountiful, such as high-frequency trading, fraud detection and self-driving cars. ■ However, in long-only public equity investing, where data availability is limited, these models may not be as effective.
Generative AI 	■ A product of recent breakthroughs in deep learning, "GenAI" is adept at producing creative outputs such as text, images, music and computer code, increasingly rivaling human efforts.	■ While GenAI is skilled at creating new images and texts, it is less effective at recognizing patterns, as it often relies on large language models (LLMs), which tend to struggle with math. ■ Because fundamental analysis and stock selection depend heavily on numerical pattern recognition, GenAI isn't suitable for these tasks.

Designing an AI investment framework

AI can't magically solve all our investing problems. And it's not enough to simply "add machine learning" to the investment process. Successful integration requires careful design to maximize skill and minimize error. Let's explore the practical aspects of choosing how and when to lean on AI, and where it's essential to involve human judgment.

Consider your data's information value

The goal isn't bigger data; it's "quality in, quality out."

In AI-driven investing, while the amount of data matters, it's the *quality* of that data that truly takes precedence. The concept of "garbage in, garbage out" applies here as well, meaning that managers using AI models should seek to prioritize reliable data sources and thoroughly cleanse the data to help ensure accuracy and relevance. Materiality is also critical, especially when considering the length of the dataset. For instance, training a model to detect persistent patterns in datasets with fewer than three years of history is challenging. The emphasis should be on "persistence." We're aiming to uncover patterns that endure over time, not fleeting trends. Consequently, more data isn't always better—instead, quality is the priority.

Sequence matters

In an ideal world, we could simply compile our data, throw it into an algorithm, and have the model feed us accurate stock predictions or rankings. However, as mentioned earlier, public equity investors have nowhere near enough data for deep learning models, and the data that is available is, quite frankly, an unstructured mess with a low signal-to-noise ratio.

We believe the proper sequence is to start with human domain experts who meticulously curate the data and determine what is relevant. This cleansed data is then fed into the machine learning models. Adding this step helps minimize errors related to overfitting and can enhance the accuracy of predictions. The machine learning models then go to work—scanning the universe and applying the feature set to identify stocks that exhibit patterns associated with strong historical performance. The models can then rank these stocks, providing portfolio managers with insights on which stocks are likely to excel.

With the ranks now in hand, how should managers use them?

It might be tempting to use AI-generated rankings as a preliminary filter before making final stock picks. The problem is that machine learning models often pinpoint stock opportunities that humans find boring or uncomfortable. But that's the point—identifying opportunities that humans might miss. *This capability is a significant competitive advantage for AI.* Yet the human brain is wired to resist what is unfamiliar, undermining the potential benefits of employing AI tools.

A better sequence, in our view, is to use model rankings to generate portfolios with high conviction and then apply traditional quantitative and optimization techniques to align with the risk/reward preferences of clients. In this approach, humans review each stock recommendation and retain the authority to override the system when external factors not accounted for in the data arise (e.g., solvency issues or a public relations crisis).

Fundamental analysts can still leverage the capabilities of AI models to monitor stocks for potential risks, flag stocks for review,

or highlight high-value opportunities that may have been missed. With these insights, analysts can conduct deeper investigations and make informed decisions to adjust stock weights based on the AI's analysis. This collaboration is akin to a pilot and copilot reading signals from an airplane's flight management system.

Focusing on the task at hand

When considering whether AI is suitable for an investment task, it is important to consider both the nature of the task and its complexity to determine whether an AI model is likely to yield accurate results. Understanding these factors helps portfolio managers optimize returns and avoid costly mistakes due to inaccurate predictions made by simplistic models.

The approach to AI-enhanced investing may vary depending on a mandate's parameters, such as the desired tracking error, market cap, geographic focus or investment style. For example, machine learning tends to be better at interpolation than extrapolation, making it potentially better suited to value investing.

Value investors use historical financial statements and other company information to assess potential investments using numerical analysis techniques (such as discounted cash flow analysis or ratio analysis). These metrics are typically given greater weight than market prices or sentiment indicators (such as news headlines or analyst opinions). Because value investors focus more on historical information (interpolation) than predicting future trends (extrapolation), AI models can be effective in analyzing large amounts of historical data and detecting patterns that may not be immediately apparent to humans.

By contrast, growth investing relies more on extrapolation and may be affected by events not captured in historical data, creating challenges for traditional quantitative methods. AI models still have a role, although humans may need to take a more hands-on approach, developing features for ML models and exploring alternative datasets. Outside of direct financial analysis, there may also be a role for large language models, such as identifying sentiment in earnings transcripts, news sources and other areas not reflected in financial statements.

Using the right tool for the job

1. **Deep neural networks** can be effective when dealing with large datasets that require quick analysis.
2. **Generative AI** often is best suited for creative tasks and growth areas, such as sentiment analysis, that rely largely on language.
3. **Expert systems** and **machine learning models,** when combined with human domain expertise, can help investors make more informed decisions.

Defining best practices

The Voya Machine Intelligence (VMI) team has been at the forefront of integrating AI into investment decision-making, with over a decade of experience in applying machine learning to fundamental analysis. Our novel process joins human expertise with advanced machine learning models, leveraging an architecture known as "neuro-symbolic" AI. This approach is inspired by Daniel Kahneman's work on cognitive processes, explained in his book *Thinking, Fast and Slow.*

This process aims to harmonize the strengths of humans and machines and minimize areas of weakness and potential for error. For example, humans excel at reasoning and can navigate nuanced situations, but they are prone to emotional biases. In contrast, AI models such as machine learning and expert systems excel at data analysis but lack human-like reasoning capabilities.

VMI's neuro-symbolic approach leverages these traits by employing expert-driven systems for deliberate, methodical decision-making, complemented by agile machine learning models for swift, intuitive actions. The idea is that the models can identify investment opportunities before they are exploited by others.

Neuro-symbolic approach in practice

	Focus	Tools	Description
 Data	Parsing and cleansing data	Human curation Systematic rules-based models Natural language processing	As with all long-only equity investors, our starting point is the same: We access publicly available data, spanning financial metrics, macroeconomic indicators, technical analyses and governance considerations, among others. This critical phase involves meticulously cleaning and organizing the data, separating the relevant from the extraneous, and ensuring uniformity for comparative analysis across datasets. During this step, human domain expertise plays a vital role alongside systematic rules-based models, as well as natural language processing (NLP), which is particularly useful for parsing unstructured data to enhance our insights.
 Feature creation	Determining what's material	Expert systems (informed by humans)	Our scrubbed and refined data isn't quite ready to be fed into our machine learning algorithms. An intermediary step, known as feature engineering, steers the ML models to be more effective. Our human portfolio managers draw upon their deep domain expertise to craft "features"—measurable attributes in the dataset—that have a positive correlation with future stock performance. To achieve this, they harness expert systems and tap into the wealth of knowledge within Voya's 80+ person fundamental equity platform, with an emphasis on longer-term outcomes. The result is over 250 proprietary features—such as excess capital yield, momentum of fundamentals, and scaled-up traditional factors—all of which have a demonstrated impact on stock performance. In this phase, we build out the slow-moving, rational expert systems used to guide the models.
 Virtual analysts	Identifying "bottom-up" signals	Machine learning	We can now feed the data and feature set into our machine learning algorithms. These algorithms consist largely of special neural networks that incorporate principles of Bayesian statistics to estimate the confidence in their predictions. (At a basic level, instead of saying "This is a cat," it might say "I'm 73.4% sure this is a cat.") Compared with traditional networks, this offers a more sophisticated approach, as it's more capable of dealing with uncertainty and learning from the data. VMI employs dozens of these algorithms—we call them "virtual analysts"—tasked with dissecting data, assimilating insights, and uncovering patterns faster and more accurately than humans. Each virtual analyst is tuned to evaluate stock performance over a specific time frame between 6 and 24 months, known as an "ensemble" approach.
 Portfolio construction and trade execution	Optimization, customization and trading	Hard-coded constraints Human PM oversight Algorithms	The VA recommendations are put through a traditional optimization process to help ensure risk constraints are met. Given our focus on long-only investment, trades are executed through Voya's trade desk in New York. Human portfolio managers review each trade before it is executed, though overrides are rare. This layer of human oversight helps to ensure that trades align closely with our investment objectives and risk tolerance, underscoring the importance of human judgment in the final stage of the investment process.

Source: Voya IM.

But is it a black box?

A common concern is that machine learning models tend to be opaque, which poses a challenge for allocators trying to understand the rationale behind each buy and sell decision. To address this, the VMI team has built a proprietary explainability tool that allows the models to be interrogated as to their reasons for a stock's high or low ranking. This serves two purposes: (1) It helps ensure transparent communication with clients, so they can understand performance drivers, and (2) it establishes an internal feedback loop for continuous improvement of the models.

Assessing AI strategies

Issue	Questions to ask
In the absence of big data, strategies that rely solely on deep pattern recognition are unlikely to achieve optimal success. However, combining human expertise with machine intelligence can potentially yield more effective outcomes.	**What is the investment philosophy?** **Are the models trained using an established economic rationale?**
When it comes to data, it's about quality over quantity, avoiding the issue of "garbage in, garbage out."	**How is the data being cleansed for materiality?** **Is there a human intercept between the data and the AI models?**
AI models tend to be better suited to tasks that do not involve reasoning or extrapolation into the future. In circumstances where these cognitive processes are essential (such as with growth investing), human expertise may matter more.	**What is the investment process?** **Which parts of the process are more human driven, and which are machine driven?**
AI models are not necessarily a useful screening tool. Human intuition (System 1 thinking) is likely to veto recommendations afterwards, because AI reasoning works differently than human brains. Thus, the sequence matters.	**What is the order of the process?** **How is the manager using the AI models to enhance stock selection?**
Not all AI models can add value to the investment process. For example, deep neural networks may yield inaccurate results absent big data.	**What types of machine learning algorithms are used throughout the process?**

While AI offers great potential to enhance investment decision-making, it also introduces complexities that demand careful attention to issues of data use, the integration of human and machine contributions, and practical execution.

This is an exploratory process that will inevitably lead to more questions, and we are committed to providing clients with the education and insights to make informed decisions.

Glossary of terms

Artificial intelligence (AI)

The capability of engineered or machine-based systems to perform functions that are normally associated with human intelligence such as reasoning, learning, and self-improvement.

Machine learning (ML)

A subset of AI that involves training algorithms to learn from and generate predictions or decisions based on previous data, without being explicitly programmed for each specific task.

Machine learning models

Algorithms created through machine learning that process input data and make data-driven predictions or decisions from unseen data, based on previous inputs.

Natural language processing (NLP)

A subset of artificial intelligence that allows computers to understand, interpret, and generate human language in a way that is useful and meaningful.

Generative AI (gen AI)

A type of artificial intelligence that is used to create new content, ranging from text to images and music, by learning from a large pool of existing data and generating outputs that mimic the original data.

Machine intelligence

The capability of a machine to imitate intelligent human behavior, encompassing many forms of AI, including but not limited to machine learning, deep learning, natural language processing and generative AI.

Voya Machine Intelligence (VMI)

The VMI team leverages machine learning models for fundamental analysis. It does not utilize generative AI in the stock selection process.

Virtual analyst

A machine learning algorithm(s) that analyzes data and looks for patterns within the data.

Human-supervised AI

AI systems operating under the guidance of humans. The VMI team employs machine learning models trained on features created by humans with domain expertise.

A note about risk

The principal risks are generally those attributable to stock investing. Holdings are subject to market, issuer and other risks, and their values may fluctuate. Market risk is the risk that securities may decline in value due to factors affecting the securities markets or particular industries. Issuer risk is the risk that the value of a security may decline for reasons specific to the issuer, such as changes in its financial condition.

Investment model: A manager's proprietary model may not adequately allow for existing or unforeseen market factors or the interplay between such factors, and even a model that performs in accordance with the manager's intentions may underperform other investment strategies or result in greater losses than other strategies. The proprietary models used by a manager to evaluate securities or securities markets are based on the manager's understanding of the interplay of market factors and do not assure successful investment. The markets, or the prices of individual securities, may be affected by factors not foreseen in developing the models. Strategies that are actively managed, in whole or in part, according to a quantitative investment model, including models using artificial intelligence to select securities, can perform differently from the market as a whole based on the investment model and the factors used in the analysis, the weight placed on each factor, and changes from the factors' historical trends. Mistakes in the construction or implementation of the investment models (including, for example, data problems and/or software issues) may create errors or limitations that might go undetected or be discovered only after the errors or limitations have negatively impacted performance. There is no guarantee that the use of these investment models will result in effective investment decisions for the Strategy.

Artificial intelligence (AI): AI—including natural language processing, machine learning and other forms of AI—may pose inherent risks, including but not limited to: issues with data privacy, intellectual property, consumer protection, and anti-discrimination laws; ethics and transparency concerns; information security issues; the potential for unfair bias and discrimination; quality and accuracy of inputs and outputs; technical failures and potential misuse. Reliance on information produced using AI-based technology and tools should factor in these risks. When using a quantitative model, including those that utilize AI, as part of an investment strategy, please note data imprecision, software or other technology malfunctions, programming inaccuracies and similar circumstances may impair the performance of these systems, which may negatively affect performance. Furthermore, there can be no assurance that the quantitative models used in managing a strategy will perform as anticipated or enable the strategy to achieve its objective. The Voya Machine Intelligence (VMI) team employs a proprietary machine learning approach to identify and exploit persistent patterns in company data. The approach leverages (non-linear) machine learning ("ML") models for fundamental analysis. The ML models employed do not utilize generative AI algorithms.

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