ON THE TRAIL OF MACHINA ECONOMICUS

Dr. Martin Prause on how Computational Economics and Artificial Intelligence are changing business.

Computational Economics (CE) is a discipline that uses computer-based models to solve analytical and statistical problems. In this insightful interview, Dr. Prause uses real-world examples to explain how CE and AI are finding practical application in business landscapes. He also reveals how AI can play an important role in improving business simulations.

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Martin Prause

Q: *Could you connect the dots for us – artificial intelligence (AI), computational economics (CE), and building 'machina economicus'?*

A: The quick and dirty answer is: CE is the application of AI methods to economics.

Computational economics (CE) resides at the intersection of economics and computation.

To understand how CE and AI connect with machina economicus, we must first know that the present economic theory is based on a set of assumptions, which are:

- People have rational preferences among outcomes
- Individuals maximize utility while firms maximize profits
- People act independently on full and relevant information

These assumptions about human behavior create the construct of a species known as *homo economicus*, the *'economic man'.* While these assumptions do not accurately represent how humans behave in the real world, they are necessary to define an analytical model to work with.

AI researchers aim to construct a synthetic homo economicus known as machina economicus (also described as the perfectly rational machine). A recent article by Parkes and Wellman explains how such an AI approach can mimic homo economicus if it can align perceptions, outcome preferences, and actions to come to a decision under uncertainty.

Predicting the next move.

Computational economics can enable more powerful business simulations and better strategic decisions.

Now, computational economics has two primary economic applications for businesses today:

Example: You wouldn't care if the GPS navigation system in your car calculates a route that takes just one minute longer than the optimal one.

SOFT COMPUTING TO SOLVE ECONOMIC PROBLEMS: Soft computing refers to a set of nature-inspired computational methodologies such as evolutionary algorithms, swarm algorithms, and artificial neural networks that solve real-world problems where traditional approaches are not efficient. This is because in many cases, it takes an exponentially long time to compute an optimal solution and the margin of benefit between the second and the optimal solution is, quite often, minor. Therefore, we can safely make do with approximations. In the business world, soft computing is used in the iterative process for high-frequency trading markets where trades are done within milliseconds. Here, an optimal solution to determine the best portfolio or to forecast the financial markets cannot be calculated efficiently, hence, an approximation is the next best option.

A recent article by Parkes and Wellman explains how AI can mimic homo economicus if it can align perceptions, outcome preferences, and actions to come to a decision under uncertainty.

COMPLEX SYSTEM MODELING TO UNDERSTAND BEHAVIOR**:** A complex adaptive system (CAS) is a system where 'agents' autonomously interact with each other. Simply put, an agent is a unit that senses its environment, follows process rules to react to the environment and its internal state, and propagates its result to other agents for interaction. The main advantage of CAS over traditional analytical systems is the study of how specific phenomena emerge. As CAS is self-organizing, it allows non-linear behavior to emerge depending upon internal system changes as well as environmental changes.

Agent-based modeling (ABM) is a specific CAS model to study the economic dynamics, i.e., how agents behave, providing a better understanding of the system. It does not focus only on outcomes – rather it focuses on how the outcome materializes. In other words, it is a methodology to study behavior. ABM can be used in social networks to simulate interactions, consumer behavior, word-of-mouth advertising, innovation diffusion, etc. Generally, ABM is used to generate what-if scenarios for companies and governments seeking to establish policies, regulations, and forecasts.

In the words of Arthur Samuel (1959), AI is the "field of study that gives computers the ability to learn without being explicitly programmed." Taking a helicopter perspective, AI consists broadly of three fields: knowledge representation and optimization, automated analysis of data, and learning (i.e., machine learning).

What is the link between CE and AI? First, from a theoretical view, CE and AI use the same methods to solve problems. While one is tailored to economic applications (CE), the other is not tailored to any application (AI). Second, from an application perspective, AI can enrich agents in complex adaptive system modeling. Thus, agents gain cognitive abilities to match or increase real-world representation.

In summary, thanks to CAS, we can study not only equilibriums or specific outcomes, but also how they are formed. Additionally, if the agent's behavior mimics human behavior closely, the micro and macro dynamics can be better understood.

Example: There were many publications that tried to assess the impact of Brexit and the recently discontinued Transatlantic Trade and Investment Partnership (TTIP) on foreign direct investment (FDI).

Q: *How can AI be incorporated in business simulations and how can this help companies deal with complexity and uncertainty?*

A: Business simulations are computational simulations that mimic companies and their strategic environments such as internal views,

competitors, customers, suppliers, and PEST – political, economic, social, and technology aspects. In education, such simulations are used to teach how all business elements are connected. In industry, they are used to conduct what-if analyses using appropriate assumptions and simplified models of the real world. There are many systems in place that give companies different views: ERP systems give an internal view, CRM and digital marketing offer an external view, and competitive intelligence systems provide perspectives on the strategic environment.

If the information provided by these three systems is aggregated and fed into an appropriate model, it can be used for scenario analyses and market forecasts to align strategies across all business units.

So the key question for business leaders is: Can my company define and execute a strategy consistently and coherently in this environment?

A book called 'The Second Machine Age' (2014) by Andrew McAfee and Erik

The cognitive and heuristic shortcuts humans use to cope with constraints that are prone to discrepancies with objective reality:

- *Myopic problem representation – Where a problem is oversimplified and important variables are overlooked*
- *Group think – A cognitive bias that occurs when the demand for harmony within the group outweighs the need for critical thinking*
- *Conjunction fallacy – Based on misjudgment, where the more detailed information an individual has on a specific event, the more plausible this event is perceived to be, although it might be less probable*
- *Confirmation bias – Information that confirms existing beliefs and mental models, leading one to neglect contradictory evidence*

ABM modeling focuses not on outcomes, but on how it materializes.

Brynjolfsson talks about how data generation and usage will increase exponentially in the near future, particularly if machines can train themselves to get better instead of just learning from the past. Digital systems move at a faster pace than other systems in society, adding to the complexity and uncertainty.

Here, AI comes into play when it leverages the agents of the *machina economicus* paradigm in a business simulation. First, one can study the dynamics based on more advanced models. For example, instead of using the analytical supply and demand model, consumers and suppliers can be represented as agents with desires, objectives, and cognitive capabilities. This could help to demystify the complexity and uncertainty of the company's environment. Second, to conduct a sound what-if study, hundreds of assumptions have to be tested. Therefore, thousands of simulations have to be tested. We must then identify patterns and study the outcomes. This is where machine learning comes in to identify patterns of dynamics and correlate them with outcomes.

The next step is to relax some of our earlier assumptions in the *homo economicus* model, thereby making the outcomes closer to reality, where human beings are subject to cognitive biases. Human decision making in daily life or professional business is subject to lack of information, processing time, and limited resources.

Once models can also account for this systematical error, businesses can achieve a better understanding on how they should approach their suppliers or how they should plan their marketing campaigns, etc.

Example: Daniel Kahneman and Amos Tversky (1973) demonstrated that humans use shortcuts to cope with these constraints and that these cognitive representations and heuristics are prone to a systematical discrepancy to objective reality.

Q: *What are the ways in which AI can be used for a company's business model and decision-making process?*

A: Let's move away, at least temporarily, from the idea that AI is a cognitive, super-intelligent, artificial processing unit and instead focus on the AI methods, i.e., knowledge representation, learning, and optimization. Today, the market for AI applications is very fragmented and there is a lot of buzz around this approach. However, in most cases, AI refers to some form of machine learning or soft computing specific tailored to a particular application. In fact, many companies / start-ups in the European market are promoting AI methods across the value chain, and they primarily use either optimization techniques or machine learning.

In contrast to the tailored use of AI methods, there are also leading players who are already working on a machine with the capacity to learn 'the way a baby or an animal does'. This is interesting because this machine is actually learning by 'observing the world', not by being trained. This approach closes the loop and aggregates the elements of knowledge representation, learning, and optimization to support a wider range of applications.

Some examples:

- **Marketing:** Wunder.ai is matching people and products using algorithms.
- **Inventory:** Cargonexx has optimized the utility of cargo space on its trucks, thereby matching demand with supply.
- **Operations:** MicroPsi uses AI to control industrial processes and systems.
- **Development:** EyeQuant uses AI to provide automatic A/B testing for mobile app / website design.

For each element, there are multiple solutions.

Q: *AI has also precipitated concerns for businesses such as job automation, fooled AI, etc. What are the pitfalls and how can businesses avoid these?*

A: Let me elaborate on some of the basic concerns that hinder the acceptance of AI:

FEAR OF LOSING CONTROL ON DECISION-MAKING: Humans are subject to many cognitive biases and machines can easily exploit these. Do you think that we have free will when we navigate a website? No; the components in a well-designed website are placed to achieve a certain goal.

Computational economics is about identifying patterns and studying the outcomes. This is where machine learning can play a huge role.

There are other fears: Machines can easily use framing or anchoring techniques to influence our behavior, or machine-learning systems may use people's digital trails and incorporate undisclosed traits into their own decision-making.

NON-TRANSPARENT USE OF DATA: Eric Horvitz and Deirdre Mulligan highlight that social network posts can be used to determine if a person has depression. While this is good to help us initiate treatment for that person, groups with vested interest can secretly use such data against this person.

UNCERTAINTY OF THE DECISION-MAKING PROCESS: The use of machine learning is increasing, yet organizations lack understanding of how computers arrive at decisions. Is the machine programmed to be biased towards a specific company goal? How does the machine resolve ethical dilemmas such as the much debated 'trolley problem'?

UNANSWERED LEGAL QUESTIONS: Who becomes responsible when the outcome of a machine is not aligned with the law or cultural standards? What if an AI-controlled traffic signal learns that it is more efficient to change the light one second earlier than was previously done? While this may be more efficient, perhaps it can lead to more accidents.

OPENNESS TO MISLEADING INPUT: AI methods can be fooled. It took less than 24 hours for Twitter users to corrupt Microsoft's AI chatbot, Tay, into making racist comments. Nguyen, Yosinski, and Clune demonstrated how an artificial neural network (ANN) for image recognition was fooled into believing that images which were unrecognizable to human eyes were actually familiar objects.

Q: *How do we avoid those pitfalls?*

A: One approach is to establish standards that are accepted by society. Just as car manufacturers have to adhere to specific norms to sell their cars, AI designers and developers should also adhere to specifications and follow norms on how decisions are taken, although this is a difficult approach as there is no one definition of AI. Nevertheless, some organizations such as OpenAI, are already heading in this direction. Even the legal and governmental system should adapt to the rise of AI in daily private and business life to purposefully regulate the use of data.

Soon, machines may be able to learn by observing the world, and not simply by being trained.

About the Author

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Martin received his Ph.D. in economics from WHU in 2014 and was granted two research scholarships: in India (Infosys, 2013) and Japan (University of Tokyo, 2015). From 2012 to 2014 he has been involved in joint research projects with the London School of Economics and Google Inc. in the Google Summer of Code Program. Before he started his doctoral studies, he received his MBA degree, worked as the Head of IT for three years in a small- and medium-size company, and graduated from the Technische Universität at Dortmund with a diploma in computer science.

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