Bio-based Industries Consortium

AI as a game changer for the bio-based industries

The recent popularity of tools like ChatGPT has led to hype around the use of AI based on language models: at last, computers seem to understand people and provide answers that are useful to us. At least, these answers sound convincing, if not always verifiable. Is AI reliable enough for application in the bio-based industries? Can it actually make processes more efficient? And does it really lead to new insights, or are we dealing with an automated parrot that repeats past results?

Some members of the Bio-based Industries Consortium are already using AI extensively in practice for a variety of tasks. They use it as a tool for R&D, but also for optimising production processes and searching for new bio-circular value chains.

AI is accordingly a broad field of knowledge (Fig.1) in which the computer does what it is good at: creating order in data that is so vast that a human quickly loses the overview; making predictions based on probability calculations; and making rational decisions in a split second, without being distracted by emotions or personal preferences (Fig.2). It is something computers have been used for since the sixties.

Fig. 1 What is AI?

AI, an abbreviation of Artificial Intelligence, is an aggregate term for algorithms and methods by which computers perform tasks once thought to require human intelligence, such as reasoning, learning, planning and creativity.

AI enables technical systems to perceive their environment, deal with these perceptions and solve problems to achieve a specific goal. AI systems are able to adapt their behaviour to some extent, by analysing the effect of previous actions and working autonomously.

Some AI technologies have been around for more than 50 years, but advances in computing power, the availability of a huge amount of data and new algorithms have led to significant breakthroughs in AI in recent years. For instance, generative AI is currently in the spotlight since the emergence of ChatGPT. This includes understanding natural language and -based on that- generating texts, images, audio, and videos.

This is made possible by 'deep learning' technology that uses neural networks. These networks work in a similar (but not 100% the same) way as the human brain: learning (in this case machine learning) is not a simple linear process based on decision trees or the clustering of data, but takes place simultaneously through completely different paths.

AI now has a wide range of applications: expert systems, speech recognition, planning and scheduling, computer vision, robotics, automatic reasoning, fuzzy logic (dealing with uncertainties).

AI offers industry a wide range of opportunities to improve processes, cut costs and develop new products and services. It is a technology that has the potential to radically transform and optimise industries.

Take the Dutch company **Process Design Center (PDC)**, which has developed several expert systems for the design of industrial processes, including bio-based production and chemical recycling. These allow such processes to be designed or optimised, from pre-processing through fermentation to downstream processing. Parameters such as the desired yield, purity or energy efficiency can be entered as required. The system provides one or more suggestions for the selection of reactor systems including fermenters, as well as for the design of separation sections.

Hans Keuken, founder and CEO of PDC, compares the functioning of the system to the way a doctor works.

He asks you questions and based on the answers you give, certain possibilities are ruled out. Follow-up questions refine the diagnosis. In the end, a number of solutions remain, for which the probabilities can be calculated.

Hans Keuken, founder and CEO, PDC

Fig. 2 An influential black box

AI systems have a major impact on society. They are often seen as 'black boxes' capable of presenting decisions with great persuasiveness on the basis of faulty or incomplete data, flawed analyses, software errors and absence of ethical considerations. The consequences can range from non-viable investments and political deception to environmental and health damage. Or worse.

Decisions based on data and pattern analysis that affect personal privacy are being made already. These include the use of algorithms that determine what information is shown to social media users (and what remains hidden), or that pinpoint individuals as potential shoplifters, fraudsters or terrorists. The military use of AI raises even more questions, where matters of life and death are involved. But in business too, decisions made by AI systems can have far-reaching consequences if insufficient ethical controls are built in. Consider the emphasis in an AI model on efficiency and profitability against safety, equality, social security or the potential long-term impact on climate, health or employment.

That is why the European Parliament is working on a regulatory framework for AI, as part of its Digital Strategy. This so-called AI Act should guarantee that AI systems used in the EU are safe, transparent, traceable, non-discriminatory and environmentally friendly. AI systems should be overseen by people, rather than by automation, to prevent harmful outcomes. It will be the world's first comprehensive AI law.

Read more on the **European Parliament website**.

Wrong choices

Thus, the expert system helps, for example, in the selection of a reactor or a separation process. People tend to make such choices based on past experience, even if current processes are completely different. "In 90 per cent of cases, a less efficient reactor is chosen than would be preferable based on the pure data."

The subsequent separation process can also be quite complex. Keuken: "The fermentation fluid from the reactor sometimes contains multiple azeotropes (pairs of components that are very hard to separate). How will you remove these from your product? Through distillation with an auxiliary agent? Extraction? Crystallisation? Or by using a membrane? Which membrane, when you have a choice of 20,000 variants?

The possibilities for separation sequencing are endless. As a human, it is easy to get off track and make wrong choices. The computer, however, easily calculates thousands of variants. Sort of like a chess computer thinking several moves ahead. You can think of it as a team member that is good at maths. The expert system then suggests the most efficient solutions, after which the human expert makes the final decision. This hybrid way of working is ideal."

Many unknowns

Pieter Coussement, senior data engineer and “squad leader” of Flemish **ML6** also thinks human input is vital: AI cannot yet work autonomously.

> **It can process a lot of information and provide relevant insights, but the input of a human expert, a scientist, remains crucial for assessing the data and making decisions. Especially in biology and related life science sectors, there are so many unknown factors, that human input is essential for the advancement and proper use of AI.**

Pieter Coussement, senior data engineer and “squad leader”, ML6

ML6, which has offices in Ghent, Berlin and Amsterdam, develops end-to-end AI solutions for specific applications.

For example, the company built an analysis application for scientific literature on cancer on behalf of the Maxima Hospital in Eindhoven. It unlocks a huge amount of research data via a smart search engine, which visually presents cross-references between documents. As a result, oncologists can search for possible treatment options faster and in a more focused manner. ML6 is also one of the partners of the Horizon Europe project DeCYPher (Fig.3).

AI can provide a clear added value in this respect. It can use the method of active learning to make the AI model smarter thanks to feedback, for example on predicted results of laboratory experiments. Initially, the model contains mainly historical data, but these are gradually supplemented by enrichments, assessments and corrections from a human expert. In this way, predictions become increasingly accurate.

This approach ultimately reduces the need for time-consuming and expensive research in the physical lab (the ‘wet lab’), because large numbers of experiments can be performed virtually (in the ‘dry lab’). Coussement: “By reducing the number of physical experiments, we accelerate innovation. We no longer need to test millions of bacterial strains in the wet lab, only a few thousand that the AI model labels as promising.”

This model is used to discover and develop new enzymes, optimise bacterial strains that serve as microbial factories and optimise growth conditions in the bioprocess.

Fig. 3 deCYPher

Creating novel production process for flavonoids and terpenoids

In the **DeCYPher project** a model is being developed for the biotechnological production of terpenoids and flavonoids: a large and diverse group of natural compounds used in a variety of applications, including pharmaceuticals, fragrances and flavours, food preservatives and insecticides.

Commercial extraction of these compounds from plant material is inefficient and not very climate-friendly. Therefore, DeCYPher is searching for reliable and efficient biotechnological production methods.

Image source: deCYPher

Variations of residual streams

The process of data labelling is crucial to enable machine learning. This involves labelling raw data with relevant tags, keywords and/or categories. The AI application needs this information to organise and sort large amounts of data, but also to train a model to find 'meaning' in relevant similar data. The labelling process is important when multiple datasets from different origins are linked together.

The potential of this approach is shown by the BioLink model from the German company **VCG.AI**.The abbreviation stands for Value Chain Generator, which is VCG's speciality: an AI- and data-driven process for developing circular solutions for industry. Indeed, co-founder and CEO Jon Goriup sees that there are plenty of opportunities for valorising residual streams in Europe. "Yet, these remain largely underused and undeveloped, despite their potential positive impact on climate as well as industry profitability."

VCG's AI model focuses on how to valorise by-products and organic waste into sustainable products with the highest possible market value, such as proteins, chemicals or pharmaceutical ingredients. "Answering this question requires the AI model to identify processes that are technically and economically feasible, as well as environmentally friendly.

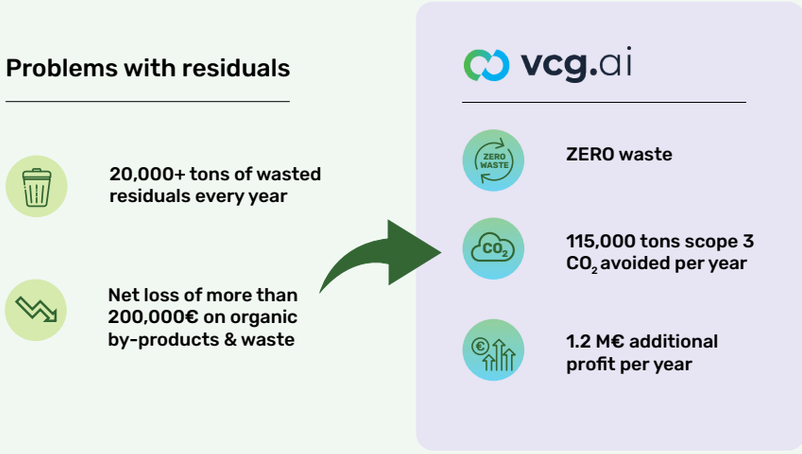
VCG trains the model with large amounts of data, from statistical data on industry and material flows within a specific region to techno-economic analyses, research papers, climate impact assessments and LCA datasets of more than 400 conversion technologies and business models."

So the AI model not only knows where to find the various by-products and waste streams, but can also evaluate matching conversion processes, technologies and market opportunities and is able to link these together.

> **In two phases of this process, we use the added value of AI. In the first phase, we use large language models so that we can really analyse and understand hundreds of thousands or even millions of different data points about circular business models and technological processes worldwide. With this, we develop our so-called BioLink models, which are basically generic representations of circular business models.**
>
> **We can also use AI to pinpoint a solution for a specific customer or a specific material flow at a specific location. We compare data from our models with those of our customers, where we can also take into account various technical parameters, such as moisture content and purity of the residual material.**

Jon Goriup, founder and CEO, VCG.AI

Fig. 4 Large multination brewery: residuals problem into 1.2M€ solution



Yeast waste

As an example, Goriup mentions a residual stream from breweries: spent yeast (Fig.4). Currently, it is processed as waste. "With our models, we can find a profitable scenario for using this residual stream for productive purposes, based on the customer's location, available quantities and a host of other parameters. With that, we managed to turn €200,000 of yeast processing costs for a medium-sized brewery into solutions that potentially generate €1.2 million in profit. This is our specialism: extracting as much value as possible from organic waste streams, helping companies make circular biobased products and finding the right supply of residues to achieve that."

VCG.AI is currently mainly focused on residual streams from the agrifood, beverage and wood industries, but the company plans to expand into other sectors, such as textiles and chemicals, in the near future. Jon Goriup invites companies operating in these sectors to contact him.

Broadly applicable

The conclusion is clear: AI is broadly applicable in the biobased industries, at micro and macro levels and at all TRL levels. It can boost the development of new circular and bio-based activities and products, and also increase the efficiency of processes and the profitability of products.

This applies not only to large corporates, but also to SMEs, according to Pieter Coussement: “Small companies can take their first steps into AI with free or relatively cheap tools. There are many service providers on the market that allow you to use AI for a modest fee. Microsoft, Google and other big players are already building it into their systems by default. Complete custom-made solutions like the ones we make at ML6 might be a step too far. However, entrepreneurs should ask to what extent they need such a customised system.

I certainly think that efficiency gains can already be made by automating some simple processes via AI. Especially for a small business, this could be a real gamechanger!”

In May 2024, the Bio-based Industries Consortium organised a webinar for members on the use of AI in bio-based industries, moderated by Marco Rupp.

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