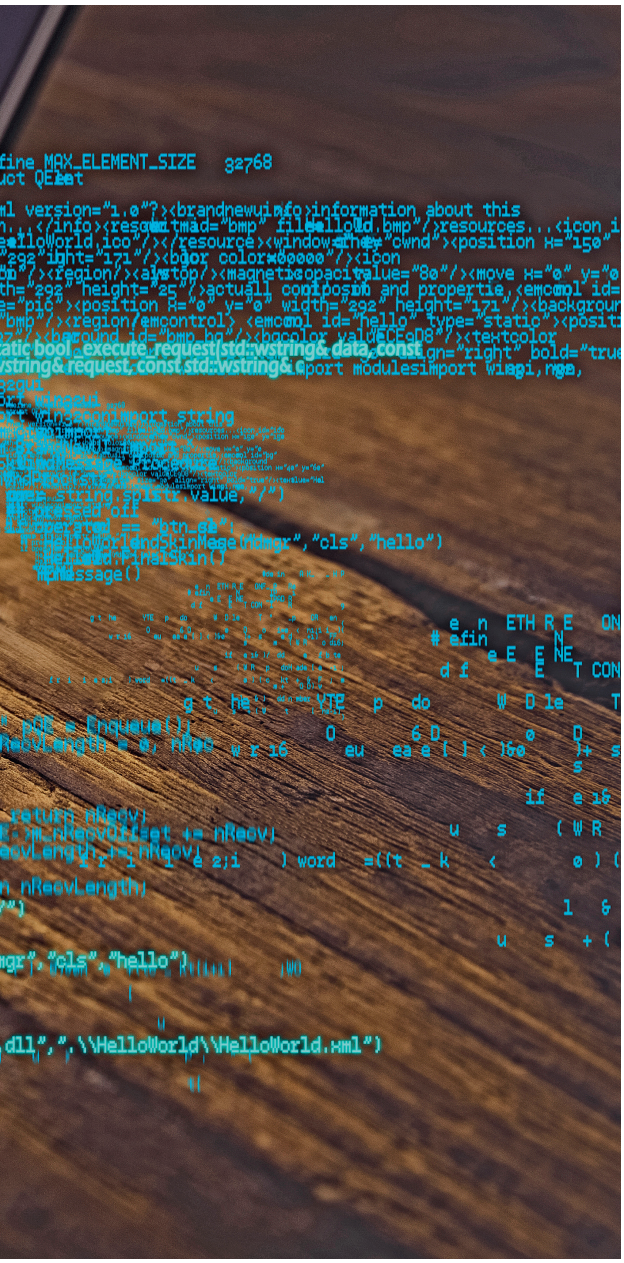
AI to the Rescue on Complex Decisions



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We all face a wide array of different choices every day of our lives. **Asst. Prof. Miłosz Kadziński** explains how artificial intelligence could be used to help us make decisions.

ACADEMIA: **What are the current global trends in the field of artificial intelligence? What are researchers devoting their time and resources to?**

MIŁOSZ KADZIŃSKI: Over the last sixty years, the development of artificial intelligence (AI) has been following different trends inspired by a demand for improvement and by the rapid technological progress. The spectacular achievements of recent years, centered around data-driven processing, are overshadowing the traditional paradigm of AI which held sway until the late 20th century.

The main focus of current research, held under the broad umbrella of artificial intelligence, is machine learning. Its key aim is to reveal observable patterns in analyzed data and to explore them to devise practical problem-solving techniques. Of particular interest is the exploration of big data, such as from the Internet, and the analysis of continuous data streams.

The development of other important areas of AI is determined by the growing availability of specific data used to uncover new knowledge. Examples include computer vision – high-level understanding of digital images – and natural language processing focusing on recognizing sounds and speech, and understanding and generating data in natural language.

Progress in this field translates into the growing use of AI in robotics, where the current goal is to adapt robots to interact with their environments in a way which can be generalized and predicted. A closely related area is the Internet of Things, where AI is used to process and use data originating from interconnected devices and objects such as household items, vehicles, buildings and cameras.

We are also seeing a renaissance in terms of the economic and social aspects of computations. This drives research into algorithmic game theory and social choice theory as well as design of mechanisms helping individuals find optimal solutions for the greater good while meeting their own personal goals.

Research into new applications of AI is frequently driven by a desire to improve the way we deal with everyday problems. In this respect, we are seeing dramatic improvements in public transport, home appliances, mobile devices and healthcare. Many of us already use AI for travel planning, with the technology either built into cars or as smartphone apps providing on-demand transport options. The arrival of self-driving cars on our streets seems to be inevitable in the coming years. Intelligent cleaning robots are rapidly growing in popularity in Poland, while progress in image- and speech-recognition algorithms means we are interacting with a wide range of devices. Diagnostic methods and decisions on how diseases should be treated now heavily depend on medical professionals using AI, while mobile devices are widely fitted with apps monitoring users' health and helping them stay fit and well. The development of AI is also bringing achievements in education, public security and entertainment, as well as in agriculture and industry which are struggling with workforce shortages.

Asst. Prof. Miłosz Kadziński (ME, PhD, DSc) works at the Laboratory of Intelligent Decision Support Systems at the Institute of Computer Science at the Poznań University of Technology. He specializes in computer-assisted decision making. He is the winner of several awards in Poland and abroad, including the Prizes of the Prime Minister and the Minister of Science and Higher Education in 2018 and the Academic Prize of Division IV: Technical Sciences of the Polish Academy of Sciences.

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Your main area of research is multiple criteria decision analysis. Tell us more about the kinds of problems you work with.

The core aim of this discipline is to develop tools which will allow us to solve decision problems where potential alternatives are assessed from many, often conflicting points of view formalized by evaluation criteria. Multiple criteria decision analysis tends to evade simple scientific classification. It is perfectly reasonable to see it as one of the most important trends in contemporary computer science, although it should also be said that it is an interdisciplinary field, with IT intersecting with economics, mathematics, cognitive science, psychology and political science. When they are analyzed together, they can help us tackle multiple criteria problems.

If you need an example of the significance and widespread presence of multiple criteria problems, consider that every single day billions of people around the globe make decisions regarding buying goods and products based on their price, value, and quality. They do this without consciously thinking that they are solving a problem based on multiple criteria. Other types of problems considered in this category involve organizing decision alternatives from the worst to the best, or assigning them to pre-defined and ordered classes. An example of the former is ranking study programs which must include the reputation of the university, quality of teaching and career paths taken by graduates. In turn, an example of a multiple criteria sorting problem is assessing credit scores to companies, which boils down to assigning them to a single risk class on the basis of their position in the market, management, profitability, cash flow, and financial structure.

> There is no greater pleasure for researchers than discovering that their algorithms are being used for solving real-world problems.

Multiple dimension and conflicting descriptions of decision alternatives are typical of all decision making problems in fields such as transport, management, medicine, banking, spatial development, engineering and environmental protection. In all these problems, analysis of performances of alternatives on the individual criteria is insufficient to comprehensively solve the decision problem. This means that multiple criteria analysis methods must account for the preferences of decision makers, and their main goal is to recommend decisions which most closely follow the value systems of participants in the decision making process.

What is the path from simulating the decision process to solving the real problem?

Supporting real decision processes involves several stages which may also be interspersed with loops. The stages include modelling the decision problem, gathering information on the preferences of the decision makers or stakeholders, using this information to construct a mathematical preference model, and applying this model to aggregate performances of different alternatives, developing recommendations and generating dedicated justifications.

Key elements in the modelling stage are defining the decision problem, identifying the stakeholders involved in making the final decision and any factors limiting it, and describing decision alternatives, criteria and assessments. For example, I recently helped select a supplier for a company in the food industry in India; the decision makers were managers of departments responsible for sales, production and food safety. The set of alternatives included several suppliers who met preliminary requirements in terms of volume and delivery times. The assessment criteria reflected three branches of sustainable development, referring to economic, environmental, and social aspects.

The following stages of the decision process require an in-depth understanding of computer science, therefore they open the field in terms of original implementation. They concern representing subjective preferences of decision makers in terms of parameters of mathematical knowledge models. The process is known as preference modelling. The model constructed as a result allows us to aggregate assessments of individual alternatives in a way which reflects the decision makers' reasoning, and to develop recommendations in accordance with their preferences. The stage must be adapted to the type of problem under consideration, the format of the expected result, characteristics of criteria and assessments, availability of preferences and the number of stakeholders.

Frequently, defining recommendations is not the end of the decision process. Instead, the results could contribute to updating or expanding stakeholder preferences as their understanding of the problem improves. They may also request that we provide an explanation of our findings to help them make better sense of the recommended decision, or study scenarios of improving the value of assessments of certain alternatives to make the recommendation more helpful.

Given the scale of the challenges present at all stages of the decision process, the role of analysts is essential. They serve as mediators between the world of supported decisions and the stakeholders who usually

do not fully understand formal methodology. Their task is to ask the decision makers relevant questions and interpret their answers to select the most appropriate method, and then ensure progress by implementing each stage. Analysts combine an in-depth understanding of mathematical models, computational intelligence methods, and programming with practical implementations in the context of real decision problems.

What is your research dream?

When it comes to supporting decision making, my dream is that the methods I am developing will be used in solving real decision making problems. This has already happened several times, but I would like for the scope to be far greater. For researchers there is no greater pleasure than discovering that their algorithms or software are being used by other people for solving problems which are significant for individuals, companies, institutions, or society as a whole.

I also have another dream: I want to write a book explaining decision making in simple language. The kind of research articles we work with every day require certain formalities and schematics which aren't very accessible to ordinary readers. During my lectures at the Poznan Institute of Technology, I try to use language which is less filled with jargon to make it more accessible to students. However, transferring this to paper (or pixels!) is by no means a simple task, and it's likely to take me a few more years to fulfil this particular dream.

I also think that it is important for all scientists and researchers to search for new challenges and stimuli. In my case it's developing methods and algorithms which would enhance decision making processes with aspects typical of other disciplines of algorithmic decision theory. They include machine learning, evolutionary multiple criteria optimization, data envelopment analysis, social choice theory, group decision making and negotiation. Conducting research at the intersection of different disciplines allows me to use the knowledge and experience from any of them, as well as facing up to problems scholars in other fields are just starting on or which they are yet to tackle. Discovering new scientific disciplines is a truly fascinating journey which helps me stave off fatigue with spending long years working in a single field.

Multiple criteria decision analysis is one of the fields of AI research with applications in economics. Do you conduct research into other areas of AI at the Laboratory of Intelligent Decision Support Systems at the Institute of Computer Science at the Poznan University of Technology?

Many members of our team started their research careers by developing methods of multiple criteria decision analysis. This makes sense, given that Prof. Roman Słowiński, director of the laboratory, is one of the leading experts in the field of computer-aided decision making. Although this is still the leading discipline in our team, the scientific interests of our over twenty team members have been branching off in new directions over the last fifteen years. However, the vast majority of their research is still centered around active information systems which are able to learn from data and adapt to changes in their environment.

In terms of machine learning, our research mainly concerns labelling Internet resources, including multi-label classification, data stream analysis, big and imbalanced data, recommendation systems and incremental learning systems for complex prediction problems. We are also highly successful in the field of multi-agent systems and artificial life simulations. We mainly conduct research into constructing intelligent agents operating in assigned environments, evolution of competing robots and validation and verification of simulation models.

> Artificial Intelligence is propelling dramatic improvements in public transport, home appliances, mobile devices, and healthcare.

We also conduct extensive research into optimization and modelling of complex systems. Its results have practical applications in transport, logistics, and production planning. Members of the laboratory also work on advanced image-recognition systems which are already proving highly useful in visual diagnostics, process monitoring and medical image analysis. The systems are increasingly based on deep neural networks. I should also mention new research geared towards automatic generation of mathematical models and synthesis of computer programs, consistent with the set of tasks at hand as test examples or limitations.

We can use our expertise and experience to solve many real technological, manufacturing, business and medical problems. I hope that Polish companies, public benefit organizations and governmental and non-governmental institutions will make the most of our skills.

INTERVIEW BY **DR. JUSTYNA ORŁOWSKA**