Design Problems and Knowledge Management

Electronic Journal

Volume 2, Issue 1

January – February 2024

In this issue:

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Date of publication: February 25, 2024

Citation recommendation (Harvard style):
Author (2024) *Article title*. Design Problems and Knowledge Management, 2(1): *pages*. https://spirochkin.wixsite.com/info/journal. Accessed *date*

What artificial intelligence brings to aviation: new opportunities or new risks?

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Abstract

This article discusses the problem of the ambiguous impact of Artificial Intelligence being implemented into aviation systems on flight safety. On the one hand, computer technology, which becomes the carrier of “intelligence”, surpasses humans in terms of the volume of information processed, processing speed and the ability to minimize errors, so it is in demand at all stages of the life cycle of an aircraft or ground-based aviation complex – from design to operation inclusive. The demand is also determined by the ability of “intelligent” devices to find signs of possible adverse events in large arrays of data that change over time, process insufficiently certain or fuzzy information, and self-learn.

Together with these favorable circumstances, new risks come. In particular, when neural networks, subject to machine learning, are embedded in control loops, the methods used to ensure safety become opaque to humans, verification of control algorithms is difficult, and additional uncertainty arises. Therefore, at the moment, the use of such elements of Artificial Intelligence in critical situations with the possibility of a catastrophic outcome raises reasonable doubts.

A constructive approach to the problem under consideration may consist in the gradual and phased implementation of “intelligent” controls into aviation systems, thereby reducing the potential for uncertain hazards, with accompanying studies of risk components during operation.

Keywords: artificial intelligence, information technology, safety, uncertainty, risk.

Introduction

The use of Artificial Intelligence (AI) is currently considered as a guarantee of breakthrough achievements in almost all spheres of human activity. Since John McCarthy, an American computer programming specialist, coined the term in 1956, AI has been associated with computer systems. It stands for: 1) the property of computer systems to perform functions inherent in human intelligence, and 2) the field of science and technology associated with the creation of such systems.

The AI area includes expert systems, knowledge bases and logical inference systems, image recognition systems, large language models, machine learning, neural networks (the list is non-exhaustive). The signs of the “intelligence” of the corresponding computer programs in comparison with “ordinary” software (for example, implementing computational methods) are considered to be the abilities:

- to find stable patterns and statistically significant relationships in large arrays of data characterizing the object of analysis in an insufficiently certain way,
- to use fuzzy logic capable of handling the “small-large”, “better-worse” and other similar relationships,
- to self-learn by changing the processing models (algorithms), embedded in the programs, in accordance with the processed data (or their part playing the role of a training set).

Since all these manifestations of "intelligence" are realized by electronic circuits that perform arithmetic and logical operations, AI does not (at least for now) go beyond the boundaries of information technology, making up its specific, rapidly developing part. Modern aviation systems (as well as aerospace, energy and other engineering complexes) rely heavily on computer-aided, information-centered support for their life cycle. The purpose of implementing AI is to give this support a new quality: the plasticity inherent in human nature.

Statement of the question: whether computers are capable of intellectual activity belongs to Alan Turing, an English mathematician, one of the creators of computer technology. However, even today, 74 years after his seminal work (Turing 1950), there is no exact criterion whose satisfaction would indicate that a machine has intelligence. The main obstacle to developing such a criterion is the lack of understanding of what intelligence is, as well as mind, thinking or consciousness. Therefore, the term "artificial intelligence", in which only the first word (adjective) is justified, and something uncertain is hidden behind the second word (noun), can be misleading.

There are three main currents in the large flow of publications on the topic of AI:

1) systematization of knowledge and achievements in this topic in monographs (see, for example, (MacKay 2004), (Van Harmelen et al. 2008), (Müller 2016), (Russell and Norvig 2021), book series "Synthesis Lectures on Artificial Intelligence and Machine Learning") and reports on new research and developments in periodicals (including journals AI Open, Artificial Intelligence, Artificial Intelligence Review, ACM Transactions on Intelligent Systems and Technology, Foundations and Trends in Machine Learning, IEEE Transactions on Pattern Analysis and Machine Intelligence, IEEE Transactions on Fuzzy Systems, IEEE Transactions on Neural Networks and Learning Systems, International Journal of Information Management, Journal of Machine Learning Research, Nature Machine Intelligence, and many others),
2) critical debriefing of illusions and debunking of myths related to AI (Darbinyan 2021), (Larson 2021), (Hanna 2023), (Schagaev 2023),
3) discussion of real and potential hazards accompanying the implementation of AI elements (Saraçyakupoğlu 2020), (Bailey 2023), (McKinsey Global Institute 2023), (NIST AI 100-1 2023), (SecurityLab 2024).

It is becoming increasingly obvious that with the development of AI, in which huge financial and intellectual resources are being invested (McKinsey Global Institute 2017), not only new opportunities are opening up, but new risks are also emerging.

This problem is considered below from the point of view of an engineer who participated in Russian aerospace and nuclear projects. Elements of AI played a significant role in them, although the term itself was not used.

Opening opportunities

Information technology (covering all existing elements of AI) increases the productivity of information processing due to performing operations by electronic circuits instead of the human brain functioning on biological principles. Along with increased productivity, the following becomes possible:

– elimination of errors that occur when processing information "manually" as a result of insufficient qualifications, dishonesty, inattention, forgetfulness or fatigue of a person,

- storing data on electronic drives for an unlimited time and transmitting it almost instantly via electronic communications,
- protection of data from unauthorized access, including that by intruders.

All this ensures a higher quality of output information necessary to justify the decisions to be made. Due to increased performance and quality, it becomes possible to process large amounts of data, including time-varying one, with rapid achievement of results previously unattainable.

The use of information technology in the design of aircraft, spacecraft, power plants and other complex systems allows designers to analyze many variants of their implementation and optimize them according to several criteria. Through electronic communications, a “seamless” transfer of design data can be provided to participants in the post-design stages of the system's life cycle: manufacturers of its elements, assembly plants, construction, testing, operating and repair organizations, as well as feedback from operation to design. Interaction in an integrated information environment (IIE) eliminates such shortcomings of traditional cooperation as errors in data transmission through paper documents, converting them into input data for local computers and transferring the processing results back to paper carriers, unavailability of a part of the data for end users and even loss of important information, long approvals of any changes. It is believed that end-to-end information exchange in combination with other life cycle management methods can reduce the financial costs of creating and operating a technical system and reduce the time required for work. In the aerospace industry, certain indicators of financial and time costs can be reduced by up to 50% (Alemanni et al. 2008).

The author, together with colleagues, was engaged in the conceptual development of IIE for a reusable transport system that was to replace the *Energia* launch vehicle and the *Buran* spacecraft (Spirochkin et al. 1992), and then participated in similar work on computer-aided, information-centered support for the design of nuclear installations (Spirochkin and Evropin 2008), (Spirochkin and Atroshenkov 2009). It can be added that the *Energia-Buran* project provided for the pre-launch check based on an expert system (one of the directions of AI). The concept of IIE for nuclear installations included the possibility of using neural networks as an alternative to traditional engineering calculations aimed at substantiating structural strength (e.g. finite element analyses).

No less than when creating a technical system, the means of “intelligent” information processing are in demand at the stage of its operation. The author considers as their main applications in aviation the following:

1) monitoring the condition of an aircraft and its environment in real time to prevent critical situations (caused by technical malfunctions, weather conditions, human factors, etc.),
2) control in critical situations in order to prevent them from escalating into accidents, and
3) ensuring the survival of aircraft occupants if an accident could not be prevented.

The key advantages in these cases may be such properties of automatic control based on information technology as high performance and quality of processing large amounts of data. The preference for “intelligent” controls is determined by their generic distinctive features (see above): the abilities to find signs of approaching adverse events in constantly changing data, process insufficiently certain or fuzzy information, and self-learn.

In a critical situation, its rapid recognition is required, the determination of an algorithm of actions to compensate for deviations or minimize the hazard, and the implementation of this algorithm. A critical situation in flight can turn into an accident in a very short time, comparable to a delay in human reaction. Thus, control aimed at returning to normal flight mode or rescuing occupants in an accident that has begun is feasible only with the help of automatic means, the reaction of which exceeds human capabilities. Obviously, the complexity of the task of recognizing critical situations in real time and taking appropriate control measures dictates the need to use elements of AI.

Automatic “intelligent” control has no alternative when a critical situation is created by malicious actions of the operator of a technical system, for example, an airplane pilot or a terrorist who hijacked the cockpit. Such situations actually took place – see, for example, the list of aviation accidents deliberately caused by pilots with the aim of suicide (https://aviation-safety.net/database/event/SES/list) – and they cannot be excluded in the future. The recognition of malicious actions of the operator, their blocking and the realization of a satisfactory outcome should be carried out exclusively by automatic means containing elements of AI and operating at a speed ahead of human reaction.

The above are just some of the prospects for the use of AI in aviation systems – those that promise to improve flight safety. More detailed information on relevant issues can be found in the author's book (Spirochkin 2023).

Emerging risks

The Russian national standard GOST R 51897, similar to the ISO Guide 73:2009, interprets risk as “the impact of uncertainty on the achievement of goals” and contains a note that “risk is often expressed through ... the consequences <of a possible event> ... and the probability”[1] (GOST R 51897-2021). Thus, the risk of an adverse event can be represented by a combination of two indicators: one describes the severity of the harm caused by this event (to human life or health, property or the environment), and the other characterizes the uncertainty or probability that the event will occur. An analogous two-component representation of risk is used in the ICAO’s Safety Management Manual, Doc 9859 (ICAO 2018).

According to the ideas of the beginning of the XX century (Willett 1901), (Knight 1921), shared by some researchers in our time (Stirling 2007), (Aven and Steen 2010), the concept of risk does not cover all manifestations of uncertainty, but only those for which the probability can be estimated quantitatively, i.e. it is applicable to aleatory, or stochastic uncertainty. If quantification of the probability is not possible, in particular, due to the lack of statistical data, then the use of the term “risk” is not justified. In this case, we are in conditions of epistemic uncertainty, or lack of knowledge. It is this category of uncertainty that is characteristic of the situation with the development of AI, including the consequences of its implementation into aviation: we do not know what awaits us in the future. So, the application of the term “risk” to the prospects of AI is not entirely correct. Nevertheless, this concept is useful for analyzing prospects if we consider only one of its components – an indicator of the severity of harm.

[1] Translated into English by the author.

Summarizing the existing opinions (reflected in the third "current" of the flow of publications on the topic of AI – see Introduction), it can be argued that the potential harm from passing functions inherent in human intelligence to "intelligent" computer systems consists of three components:

1) people lose their jobs,
2) their thinking abilities degrade,
3) ensuring safety with AI becomes opaque (difficult for human control).

The history of development of any technology, including information technology, shows that, despite the reduction in employment when people are replaced by machines, a catastrophic collapse of the labor market does not occur, but on the contrary, new job opportunities open up. The arrival of computers in our lives initiated the expansion of mining and processing of rare earth elements, the emergence of industries such as the production of electronic chips, processors and other hardware components, programming, data protection, electronic communications, etc. Therefore, the first component of potential harm can only be local and temporary. In developed socio-economic systems, it can be minimized.

Things are worse with the degradation of people's thinking abilities. According to a number of sources, the highest level of intellectual development of mankind occurred in the period from the end of the XIX century to the 60s of the XX century. Since the 1970s, the growth of such an intelligence indicator as IQ (Intelligence Quotient) has slowed down, and then stopped, if it did not go backwards (Sundet et al. 2004), (Flynn 2009). Part of the community of neurophysiologists and psychologists believes that humanity is beginning to "get stupid" because it assigns "electronic brains" more and more tasks that the human brain used to solve (Kurpatov 2018, 2020). Nowadays, when any information can be obtained through Google, almost nothing needs to be memorized, found empirically and analyzed independently, most prefer ready-made answers. In fairness, other opinions should be noted. Thus, some researchers doubt that the increase in IQ observed in previous decades reflected an actual increase in intelligence, and was not an artifact or a consequence of improved nutrition, school education and other living conditions (Neisser 1997). Others suggest that progressive air pollution, which currently affects more than 90% of the world's population, is a possible reason for the decline in intelligence observed worldwide (Schraufnagel et al. 2019).

In any case, regardless of which explanation is correct, the degradation of people's thinking abilities coincides with the expansion of the presence of AI in our lives and with the transfer of an increasing number of intellectual functions to it. The power of information technology in general and existing elements of AI in particular already far surpasses human capabilities in the amount of data processed and the speed of their processing. Any superior power is a cause for concern, since it threatens unpredictable consequences when it gets out of control. Fears about the strengthening of the role of "intelligent" machines in the context of a weakening of human abilities to think increase when AI is "entrusted" with the most subtle and creative mental work, which is the prerogative of scientists: obtaining new knowledge. Neural networks are increasingly being used here, which look for patterns in the accumulated data arrays. And to create new intellectual products (texts, visual images, etc.), the use of generative AI tools based on the correlations found is becoming more and more commonplace. At the same time, such a property of the human mind as intuition is actually devalued – but it is thanks to intuition that discoveries and scientific and technical breakthroughs into unexplored areas are made.

And yet, from an engineer's point of view, the real danger of AI lies not in itself, but in the ill-considered distribution of roles between humans and machines endowed with “intelligent” functions, and in possible errors in their interaction at all stages of the life cycle. *Homo creating the machines* must do something necessary and important in which *no other entity* can replace him – establish a boundary separating their areas of responsibility, which should not be crossed.

The main applications of AI in aviation, described in the previous section, can lead to improved flight safety due to the advantages of automatic “intelligent” control. But when using neural networks in control loops, algorithms aimed at ensuring safety become less “transparent” to humans. The changeability of a neural network in the learning process (especially in deep learning) makes it difficult to understand how decisions will be made in a certain situation and what the consequences may be. Therefore, at the current stage, the use of AI for automatic control in critical situations with a possible catastrophic outcome raises reasonable doubts.

Thus, elements of AI designed to solve tasks in which their abilities are superior to human ones create additional uncertainty. It is aggravated by unintended human interaction with a machine containing elements of “intelligent” control, when the operator has a poor idea of how these elements work, or has no idea about them at all. The danger of such situations has been demonstrated by two crashes of Boeing-737-8 (MAX) aircraft: in the Jakarta area (flight JT-610, 2018) and near Addis Ababa (flight ET302, 2019). Their reasons were the installation of a new Maneuvering Characteristics Augmentation System (MCAS), which had functional flaws, and the lack of information about this system in the pilot manuals (KNKT 2019).

The risks associated with the implementation of AI in aviation are typical for any new technology (Saraçyakupoğlu 2020). The question is how can these risks be reduced?

A constructive approach to the problem

The possibilities of reducing risks (severity of harm) in the implementation of AI in aviation fit into the general risk management scheme used in innovation activities (Cocron and Aronhime 2022). The relationship between the uncertainty of the result of innovation and the indicator of potential harm (material or financial loss to the innovator/manufacturer, adverse consequences for consumers, society as a whole or the environment) is represented within the framework of fuzzy logic as four areas of their common space (see Fig. 1), corresponding to intuitively understood characteristics:

1) small uncertainty – low indicator of harm,
2) great uncertainty – low indicator of harm,
3) small uncertainty – high indicator of harm and
4) great uncertainty – high indicator of harm.

In the problem under consideration, the uncertainty of the result of innovation is “given” – it is “great”. However, developers of AI elements, manufacturers of an aviation system that includes these elements, and regulators expressing the interests of society are free to choose the magnitude of a possible threat: the indicator of harm can be reduced by limiting the amount of implementation of “intelligent” devices into the system or “intelligent” functions into the controls. In such conditions, the preferred area of innovation activity becomes one that is characterized by a combination of great uncertainty with low indicator of harm. After this choice, it is possible to study the risk components during the operation of the created system and, if necessary, modify the object of innovation.

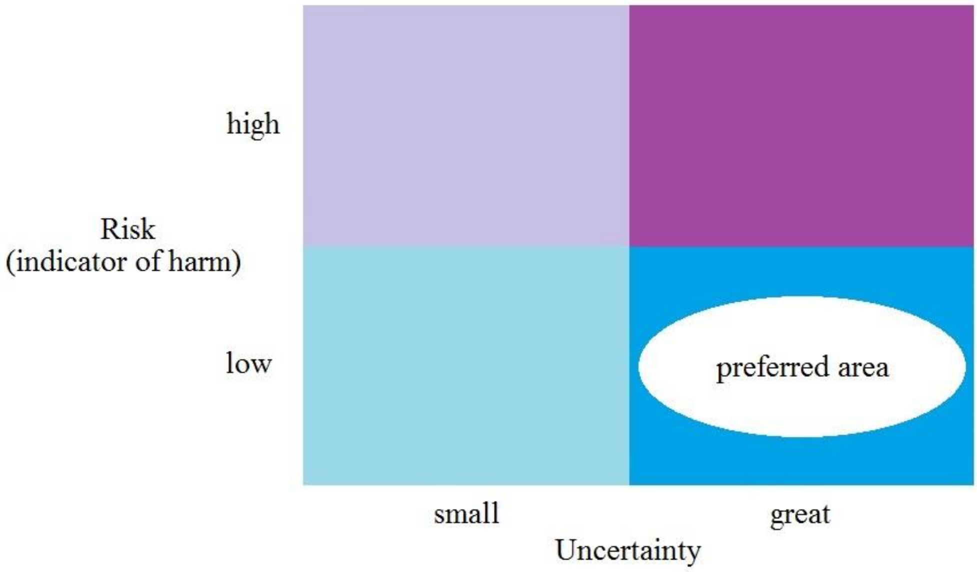

Fig. 1 Graphical representation of the relationship between uncertainty and risk (indicator of harm) in innovation

In the problem under consideration, the uncertainty of the result of innovation is “given” – it is “great”. However, developers of AI elements, manufacturers of an aviation system that includes these elements, and regulators expressing the interests of society are free to choose the scale of a possible threat: the indicator of harm can be reduced by limiting the amount of implementation of “intelligent” devices into the system or “intelligent” functions into the controls. In such conditions, the preferred area of innovation activity becomes one that is characterized by a combination of great uncertainty with low indicator of harm. After this choice, it is possible to study the risk components during the operation of the created system and, if necessary, modify the object of innovation.

A variation of the described approach is the phased implementation of AI, including verification of initial application in industries other than aviation in terms of risk levels, for example, in the automotive industry or household goods (Saraçyakupoğlu 2020).

But the possibilities of even such a cautious technical policy are limited, because according to Amara's law, people “tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run” (SecurityLab 2024).

Conclusion

Our consideration can be concluded as follows:

1. When AI is implemented into aviation, new opportunities open up that promise to improve flight safety – first of all, taking into account critical situations in which automatic “intelligent” control turns out to be crucial for the protection and rescue of aircraft occupants.
2. At the same time, new risks arise. The elements of AI embedded in the control loops of aviation systems, especially neural networks, make algorithms aimed at ensuring safety less transparent to humans and difficult to comprehend. In this regard, the use of AI in critical situations with the possibility of a catastrophic outcome raises reasonable doubts so far.

3. A constructive approach to the problem of the ambiguous impact of AI on flight safety is the gradual and phased implementation of “intelligent” controls into aviation systems, so that the potential of uncertain hazards can be reduced. Such an implementation should be accompanied by studies of the risk components during operation.
4. Since the uncertainty associated with the use of “intelligent” controls in aviation can be not completely eliminated, the role of regulatory authorities capable of directing business aspirations in the safest direction is increasing.
5. The unpredictability of AI evolution and the possibility of its negative impact on society necessitate monitoring the processes of development, implementation and use of “intelligent” devices, and reasonable restrictions (both at the national and global levels) on the precautionary principle, as well as readiness to respond to emerging threats – similar to anti-epidemic protection measures.

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Commentary to the article "What artificial intelligence brings to aviation: new opportunities or new risks?"

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The article of Dr. Y. Spirochkin describes the advantages and risks of possible implementation of AI into aviation. The author has defined three categories of advantages, namely monitoring the condition of aircraft and its environment in real time to prevent critical situations, control in critical situations in order to prevent them from escalating into accidents, and ensuring the survival of aircraft occupants if an accident could not be prevented, as well as three categories of risks (which are more general than specific): people lose their jobs, their thinking abilities degrade and ensuring safety with AI becomes opaque (difficult for human control).

Given the public's interest in AI, its ambiguous impact on people's lives and the even greater uncertainty of such an impact in the future, the ideas developed by the author of the article could be extended to the field of art or fundamental science. For example, paintings created by AI in the style of Gustav Klimt to recover his lost Trio [1] evoke emotions comparable to those that we experience when looking at the original works of the artist. But the question arises: if it was some helpful work to have an idea of the Klimt's lost works, and if the AI analyzed correlations in the existing paintings of the master and created a new similar "work", is there creativity and innovation in this?

Or, if we apply AI to the first stage of Pablo Picasso's artworks, when he worked in the style of post-impressionism (e.g. "Alicante saw the boat, 1895; "Landscape", 1895; "Head of a Woman, 1900", [2][3], is AI capable of "anticipating" or "implementing" the same unexpected and sharp turn to cubism or abstractionism, as well as implementing fundamentally new stylistic features of the artist, in particular, a specific distortion or doubling of faces (e.g. "Jacqueline squatting", 1954, or the abstracted "Nude and still life" [3], etc.)?

In the case of applying neural networks to the analysis of a huge array of data and equations of classical physics, is it possible to foresee the phenomenon of quantum Schrodinger uncertainty and derive the corresponding equation or create the theory of special or general relativity? That is, is AI applicable when a shift of paradigm in certain field of art or science occurs? We know that human creative potential plays a major role in such a shift, but can it be replaced by tools of AI?

Returning to aviation, we can consider the emergency landing of the Airbus A320-214 operating US Airways flight AWE 1549 on January 15, 2009. In an emergency situation – the failure of both engines a few minutes after takeoff – pilots Chesley Sullenberger and Jeffrey Skiles decided to splash down the plane on the Hudson River and successfully completed it, saving the lives of all 155 passengers. The initial simulations carried out during the investigation on the simulator in Airbus Training Center, Toulouse, France (which used, although insufficiently developed, but still elements of AI) showed the fallacy of such a choice ([4], p.1.16) and claims were made to the pilots. And only later, after the introduction of some actual flight data into the

[2] French Society of retired nuclear and aerospace engineers.
[3] The author has viewed other originals from the early period of Picasso on some exhibitions in France.

simulation, the crew's decision to ditching on the river was assessed as the most correct and all charges against the pilots were dropped.

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[3] source: https://www.pablo-ruiz-picasso.net/work-1373.php

[4] Loss of Thrust in Both Engines After Encountering a Flock of Birds and Subsequent Ditching on the Hudson River, US Airways Flight 1549, Airbus A320-214, N106US, Weehawken, New Jersey, January 15, 2009" (PDF). National Transportation Safety Board. May 4, 2010. NTSB/AAR-10/03. Archived from the original on November 15, 2016. Retrieved on March 7, 2017.

Editorial

Partner News: From Dr. Krause GmbH

Dr. Gerhard Krause, partner of Dr. Yuri Spirochkin in Germany, announced the publication of his new book (in German): **Wärmeexplosion. Theorie & Praxis**. Verlag Dr. Krause GmbH Berlin (ISBN 3-9809903-1-1). The contents of the book are as follows:

For more information and to order the book, please contact:

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