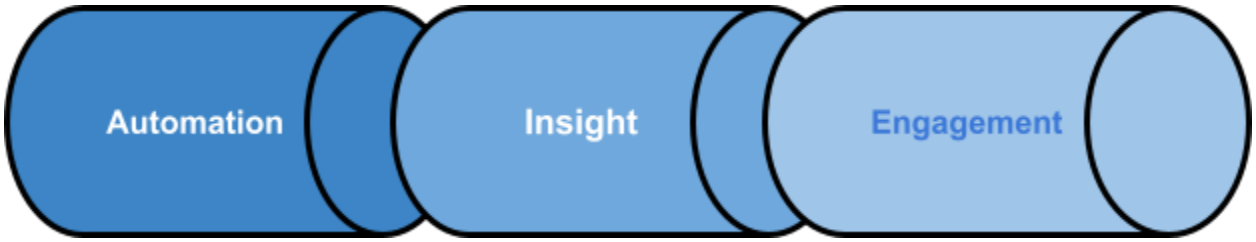
Research with AI Guidelines
by UMaine AI Steering Committee

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1. Introduction

University of Maine Artificial Intelligence (UM AI) is led by a steering committee that spans various disciplines across campus with multiple faculty and administrator members. AI, broadly defined, can potentially be useful in accelerating various aspects of research, while it also poses some challenges as described in this document. The guidelines in this document are intended to help students, faculty, and researchers understand the opportunities and challenges of AI as they navigate this powerful and dynamic toolbox. This is not meant to be a comprehensive document with specific policy details, since best practices and responsible policies for use of AI are still evolving across federal oversight agencies, academic institutions and scholarly journals. In this document, AI is divided into three major application areas: automation, insight, and engagement as shown in the diagram below. These are explained next.



2. What is AI?

The term “artificial intelligence” (AI) refers to the eponymous subfield of computer science and to the programs and computing techniques developed by that field. AI is already woven into the fabric of modern society to a remarkable extent. For example, Web search engines are based on AI, data science and data mining programs use AI to look for patterns in scientific and business data and to make predictions based on the data, partially or fully self-driving cars require AI to function, businesses use AI to analyze credit card applications and résumés, mail services use computer vision and other technologies to speed up package delivery, and automated stock market trading is powered by AI. Factory robots make use of AI technology as do modern processes for product development and drug discovery. Scientific research makes use of AI in a variety of ways, including using AI to understand and predict protein folding, using computer vision techniques to identify organisms in videos and images, speed up modeling physical processes, and using AI to help with the research tasks such as literature discovery and writing.

AI technology includes a wide range of techniques and algorithms, including: rule-based and logic-based reasoning, qualitative simulation, cognitive models, Bayesian networks for decision making (e.g., email spam filters, medical decision-making, document classification). Since the early 2000s, techniques from the AI subfield machine learning (ML) have dominated the applications fielded and the public's attention, in particular the area of deep learning. Deep learning is based on neural networks, networks of "neurons" and weights links between them that are (very) loosely based on the biological neural networks in brains. Deep-learning systems in particular have tremendous potential for use in research, and they have already been used in a wide variety of ways, including for transformer-based generative AI systems such as ChatGPT.

Societal reliance on AI technology is poised to exponentially increase in the near future, and this includes its use in scientific research. AI can be of use to researchers in several different ways. One way is ***automation*** of research processes: data transformation to meet the needs of legacy research software, finding references in the literature, controlling automated laboratory equipment and robotics, and providing aid during writing.

Another, possibly more important, use is ***gaining insight*** into the subject of research itself, things typically done by humans in the past. For example, AI-based data mining can be used both for distilling and summarizing voluminous data as well as finding important patterns in data. Computer vision techniques can be used, for example, to find and identify organisms of interest in images and videos, to analyze Landsat photos to detect properties of forest ecosystems, and to do automated censuses of wildlife. AI-based simulation and modeling can be used in the same way as other scientific models, but can be faster (e.g., qualitatively simulating fluid flow) or in some cases can solve previously unsolvable problems (e.g., protein folding, predicting the function of proteins from some genetic patterns, etc.) and provide insights otherwise unavailable (e.g., evolving novel proteins or chemical structures for medical applications). Many of these insight generation examples are drawn from current and recent work at UMaine and the larger research community.

AI can also aid in ***engaging*** audiences for scientific research, for example, by using generative, usually transformer-based large-language models (LLMs; e.g., ChatGPT, Gemini), to get advice about how to present findings for the general public and how to structure presentations. Generative AI image generators (e.g., DALL-E, Midjourney, and now Sora for video) can be used, with appropriate oversight, to illustrate difficult concepts for public consumption.

3. Opportunities in Using AI for Research

3.1. Automation

Automating research tasks can help save time and significantly speed up the research. Here are some examples of these opportunities:

3.1.1. Optimization: AI can optimize automation processes by analyzing large datasets to identify patterns, inefficiencies, and areas for improvement. This can lead to increased productivity, reduced costs, and enhanced resource utilization.

3.1.2. Predictive Maintenance: Sensor data can be analyzed by AI to predict equipment failures or maintenance needs before they occur. This proactive approach minimizes downtime and reduces the risk of unexpected breakdowns, thereby improving overall operational efficiency.

3.1.3. Process Automation: Repetitive tasks, such as data entry, document processing, and quality control, can be automated to free up human resources for more creative and strategic activities. This leads to increased efficiency and productivity across various sectors of economy, society, and service industry. Several companies offer AI-based laboratory robotics, as well, to automate routine laboratory procedures.

3.1.4. Smart Manufacturing: AI enables the implementation of smart manufacturing systems that can adapt to changing conditions in real-time, optimize production schedules, and improve product quality. This results in more agile and responsive manufacturing processes.

3.1.5. Supply Chain Optimization: AI algorithms can analyze supply chain data to optimize inventory management, demand forecasting, and logistics planning. This helps businesses reduce costs, minimize stockouts, and improve customer satisfaction.

3.1.6. Quality Control: AI-powered image recognition and machine learning techniques can enhance quality control processes by automatically inspecting products for defects or deviations from specifications. This ensures consistent quality and reduces the likelihood of defective products reaching the market.

3.1.7. Natural Language Processing (NLP): NLP algorithms can automate data extraction and analysis from research papers, patents, and other scientific literature, enabling researchers to identify relevant information more efficiently and accelerate the pace of discovery. Some makers of large-language models currently offer users the ability to create custom GPTs (Generative Pre-trained Transformers) that are tailored for

natural language understanding and generation in particular areas, such as a writing coach, research paper search and abstraction, and so forth.

3.1.8. Simulation and Modeling: AI-driven simulations and modeling techniques enable researchers to explore complex systems, predict outcomes, and test hypotheses in a virtual environment. This can significantly reduce the time and cost associated with experimental research and development. AI-based qualitative models can be used to make general predictions about physical systems without the need for solving the very complex equations underlying some domains, such as fluid flow.

3.1.9. Collaborative Research: AI-powered collaboration platforms facilitate knowledge sharing, data exchange, and interdisciplinary collaboration among researchers worldwide. This enables the rapid dissemination of research findings and fosters innovation across diverse fields.

3.2. Gaining Insight

Processing large amounts of data can provide insight on problems under consideration. Here are some best practices in this area:

3.2.1. Data Analysis and Pattern Recognition: AI algorithms can analyze large and complex datasets to identify patterns, trends, and correlations that may not be immediately apparent to human researchers. This includes analyzing genomic data as well as the enormous amount of data produced by space-based systems and particle accelerators. This enables researchers to gain deeper insights into their data and extract valuable knowledge more efficiently.

3.2.2. Personalized Recommendations: AI-powered recommendation systems can analyze user behavior, preferences, and historical data to provide personalized recommendations for content, products, or services. This enhances user experience and helps researchers tailor their offerings to individual needs and preferences.

3.2.3. Sentiment Analysis: AI algorithms can analyze text scraped from social media, surveys, and other sources to understand public sentiment, opinions, and attitudes towards specific topics or products. This enables researchers to gauge public perception, identify emerging trends, and make data-driven decisions.

3.2.4. Image and Video Analysis: AI-powered image and video analysis techniques can extract valuable insights from visual data, such as identifying objects, recognizing patterns, and detecting anomalies. This has applications in fields such as healthcare, biology, forestry, agriculture, wildlife management, astronomy, and surveillance.

3.2.5. Predictive Analytics: AI-driven predictive analytics models can forecast future trends, events, or outcomes based on historical data and statistical algorithms. This helps researchers anticipate changes, mitigate risks, and make informed decisions in various domains, such as finance, healthcare, and marketing.

3.2.6. Anomaly Detection: AI algorithms can identify anomalies or deviations from expected patterns in data, such as fraudulent transactions, unusual behavior, or equipment failures. This enables researchers to detect and respond to irregularities promptly, thereby minimizing risks and losses.

3.2.7. Interactive Data Visualization: AI-powered data visualization tools can generate interactive visualizations that enable researchers to explore and interpret complex datasets more effectively. This enhances data understanding and facilitates communication of research findings to stakeholders.

3.2.8. Automated Insights Generation: AI systems can automatically generate insights and summaries from raw data, reducing the time and effort required for manual analysis. This accelerates the research process and enables researchers to focus on interpreting results and formulating hypotheses.

3.2.9. *Hypothesis and product generation:* AI systems can be and have been used to autonomously generate hypotheses about novel compounds and their uses, chemical and protein structures that will interact with biological molecules. Recently, materials science has benefited from AI-based hypotheses about novel materials and their properties. Material selection and design of new products can be done by AI as well, often better than what a human can do.

3.3. Engaging

Engaging with automated AI agents can lead to creation of new text, code, or images that might be useful in presenting your research ideas. Here are some examples in this area:

3.3.1. Automated Literature Review: Intelligent AI agents can be used to search through vast databases of scientific literature to identify relevant research papers, articles, and publications. They can summarize key findings, extract important information, and provide researchers with a comprehensive overview of existing knowledge on a particular topic. For example, several of OpenAI's custom-made GPTs are specifically focused on providing targeted information to researchers from millions of papers. Of course, good practices are needed to ensure that no copyright infringement occurs.

3.3.2. Data Collection and Analysis: AI agents can collect data from various sources, including sensors, databases, and the internet, and analyze it to identify patterns, trends, and insights. This enables researchers to gather and process large amounts of data efficiently and derive meaningful conclusions from it.

3.3.3. Experiment Design and Optimization: AI agents can assist researchers in designing experiments by suggesting optimal parameters, variables, and conditions to test hypotheses effectively. They can also analyze experimental data in real-time, identify trends, and recommend adjustments to improve experimental outcomes.

3.3.4. Collaborative Research: AI agents can facilitate collaboration among researchers by organizing and coordinating tasks, scheduling meetings, and sharing relevant information and resources. They can also provide intelligent assistance during collaborative brainstorming sessions and decision-making processes.

3.3.5. Personalized Research Assistance: Intelligent AI agents can provide personalized assistance to researchers based on their preferences, expertise, and research goals. They can offer tailored recommendations for relevant papers, methodologies, and research tools, thereby enhancing researchers' productivity and efficiency.

3.3.6. Hypothesis Generation and Testing: AI agents can generate hypotheses based on existing data and knowledge, and then test these hypotheses through simulations, experiments, or data analysis. This enables researchers to explore new ideas and concepts more effectively and accelerate the research process.

3.3.7. Ethical and Regulatory Compliance: AI agents can assist researchers in ensuring compliance with ethical standards, regulations, and best practices in research. They can provide guidance on issues such as data privacy, informed consent, and research integrity, thereby helping researchers conduct responsible and ethical research. For example, there are projects at UMaine that use natural language processing and other AI techniques to read compliance documents, then read an app’s computer software to make sure that app satisfies the documents’ privacy requirements.

4. Challenges of Using AI for Research

Although AI can be very useful in research, there are several challenges associated with the use of AI, which need to be carefully considered and addressed by researchers. These include data quality, algorithmic bias and fairness, explainability, academic misconduct, and ethical implications.

4.1. Data Quality

Most AI algorithms heavily rely on high-quality data for training and validation. However, obtaining clean, labeled data can be challenging, especially in fields where data is scarce, noisy, or biased. Ensuring data privacy and security while maintaining data diversity and representativeness is also a concern. This is also true for AI systems that use unsupervised learning, i.e.,that detect patterns in unlabeled data.

4.2. Algorithmic Bias and Fairness

Processing the data using algorithms that may have inherent bias is another challenge. AI algorithms can inadvertently perpetuate biases present in the training data, leading to unfair or discriminatory outcomes. Addressing algorithmic bias and ensuring fairness, transparency, and accountability in AI systems is a complex and ongoing challenge, particularly in sensitive domains such as healthcare, criminal justice, and finance.

4.3. Explainability

Many AI algorithms, such as deep learning models, are often considered black boxes, making it difficult to interpret their decisions and understand their underlying mechanisms. Lack of interpretability and explainability can hinder trust, adoption, and regulatory compliance, especially in domains where transparency and accountability are crucial. While work at UMaine and elsewhere has begun to address the interpretability/explainability of deep-learning systems, and there is intense interest in the field of AI in this problem, the area is still in its infancy.

4.4. Ethical Implications

The widespread adoption of AI in research raises ethical, social, and legal concerns, including issues related to privacy, autonomy, accountability, and unintended consequences. Ensuring that AI research adheres to ethical principles, respects human rights, and benefits society as a whole requires careful consideration and proactive risk mitigation strategies. At the moment, the rapid pace of AI innovation outpaces the development of regulatory and policy frameworks needed to govern its ethical, legal, and societal implications. Establishing robust regulations, standards, and guidelines for AI research and deployment requires collaboration among stakeholders from academia, industry, government, and civil society.

4.5. Accuracy in Information

AI language models are trained on large amounts of text but when generating outputs they do not have access to the same context and constraints as during training. This mismatch can lead to models creating outputs that are inaccurate (hallucinations). While this is a general concern with all AI output, it has been frequently seen in AI-generated source citation lists. It is important for a researcher to always validate the accuracy of AI outputs.

4.6. Academic Misconduct

University of Maine academic misconduct policies should also be considered when using AI for research, noting that the user is ultimately responsible for any products or publications that resulted from use of AI. These policies are included here for reference.

4.6.1. Research Misconduct: Fabrication, Falsification, or Plagiarism in proposing, performing, or reviewing Research, or in reporting Research results. A finding of Research Misconduct requires 1) that there be a significant departure from accepted practices of the relevant Research community; and 2) the misconduct be committed Intentionally, Knowingly or Recklessly; and 3) the Allegation be proved by a Preponderance of the Evidence. Research Misconduct does not include honest error or differences of opinion.

4.6.2. Fabrication: Making up data or results and recording or reporting them. Fabrication excludes synthetic data or test data used for testing or validation.
Falsification: Manipulating Research materials, equipment or processes, or changing or omitting Research data or results, such that Research is not accurately represented in the Research Record.

4.6.3. Plagiarism: The appropriation of the ideas, processes, results or words of another person, without giving appropriate credit. For purposes of this Policy, Plagiarism excludes self-plagiarism; however, the University may prohibit self-plagiarism in other policies, procedures, rules, or handbooks. For the definition of self-plagiarism, refer to the University Faculty Handbook.

5. Concluding Remarks

In this document various opportunities and challenges in using AI for research have been presented, but by no means these are considered inclusive of all possibilities as this is a very dynamic area of research and new capabilities can emerge by the time this document is reviewed and published. Therefore, it is important to always refer to the UM AI website for the latest updates and examples. Overall, leveraging AI for research holds immense potential to revolutionize industries, drive scientific advancements, and address complex challenges in an increasingly interconnected world. For more information please see the references below.

References

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