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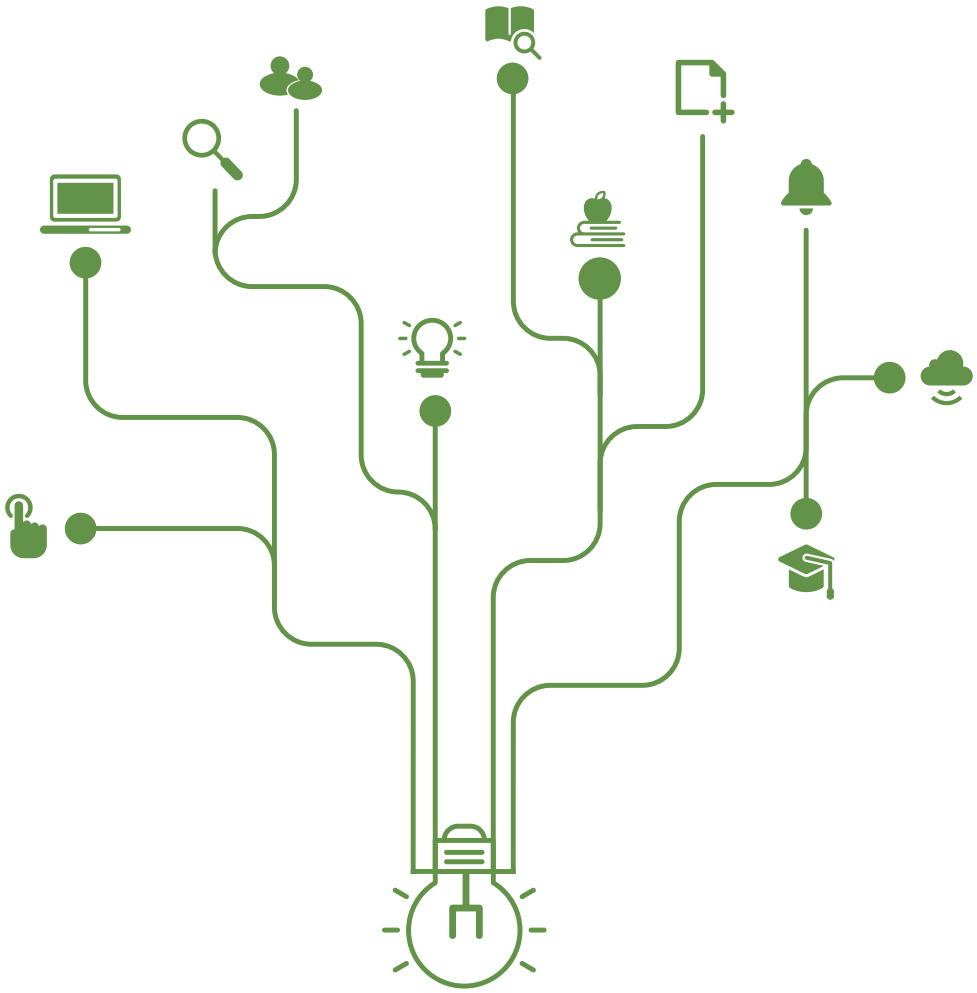

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Analyzing the Role of Governmental Organizations in Artificial Intelligence Innovation: A Patent-Based Perspective

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ABSTRACT

Artificial intelligence (AI) has rapidly emerged as a transformative technology with the potential to revolutionize numerous industries and applications. While government organizations actively support the AI innovation ecosystem through funding and policy making, their active and direct participation through patenting has not been well studied. Here, we analyzes the patenting activity of government employees and compares it to that of non-governmental organizations, focusing on the field of AI. Applying various natural language processing (NLP) techniques to the AI patents, we found that governmental organizations more focus on public benefit and national-level interests, rather than commercialization, which is a main focus of non-governmental organizations. Also, our results reveal that governmental organizations have focused on specific fields related to national security and fundamental inventions. Our findings contribute to the literature on the role of government in fostering innovation in the field of AI and have implications for policy makers and stakeholders involved in AI R&D funding and commercialization.

1. Introduction

Artificial intelligence (AI) has rapidly emerged as a transformative technology with the potential to revolutionize numerous industries and applications (Parkes and Wellman (2015)). From healthcare and transportation to finance and beyond, AI is being increasingly harnessed to automate tasks, analyze data, and make decisions (Stone, Brooks, Brynjolfsson, Calo, Etzioni, Hager, Hirschberg, Kalyanakrishnan, Kamar, Kraus et al. (2022)). As a result, the development and deployment of AI technologies has become a major focus of organizations around the world, ranging from private companies and academic institutions to government agencies and organizations.

The involvement of government organizations in AI-related R&D is particularly noteworthy given the potential societal and strategic implications of AI. Governments around the world have invested heavily in AI R&D, often with the goal of driving economic growth and competitiveness, improving public services, and addressing national security challenges (van Noordt and Misuraca (2022); Gesk and Leyer (2022)). At the same time, governments have also sought to shape the direction and governance of AI development through regulatory frameworks, funding programs, and other policy instruments (Janssen, Brous, Estevez, Barbosa and Janowski (2020); Giest and Samuels (2020)).

However, the direct participation of government in AI innovation is not well understood, and there is ongoing debate about the appropriate balance between public and private sector participation in the field. Some argue that governments should play a more active role in fostering AI innovation, especially in areas that have clear public benefits or strategic importance, while others argue that the private sector is better equipped to drive innovation and that governments should focus on setting the regulatory and legal frameworks for AI development.

In this paper, we explore how governmental organizations have directly participated in the AI innovation — beyond indirect participation, such as funding or regulating — and compare it to the participation of non-governmental organizations, to better understand the relative contributions and characteristics of government organizations compared to other institutions in the AI innovation space. Utilizing natural language processing (NLP) techniques, We analyze the trend and focus of AI innovation by governmental organizations and compare it to the trend and focus of AI innovation by non-governmental organizations. Moreover, utilizing deep learning-based natural language processing (NLP) techniques, we analyze the abstracts of patents related to AI that have been filed by government employees, as well as those filed by other non-governmental organizations. By comparing these groups, we shed light on the different motivations, priorities, and areas of focus that drive AI innovation of governmental organizations.

Our study has several key objectives. First, we seek to understand the trend and direction of the direct participation of government organizations in AI patenting. How are the AI patents filed by public and private organizations are different to each other? How have they changed over time? Second, we aim to identify the specific fields and areas of focus within AI that are most actively pursued by governmental organizations, compared to other groups. What are the dominant themes and trends in AI patenting by governmental organizations? How are they different from those of other types of organizations? Third, we examine the language and content of the patent abstracts to identify the underlying motivations and priorities of governmental organizations in AI

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innovation. How do the goals and objectives of government organizations and other institutions differ, and what implications do these differences have for the direction and impact of AI innovation?

Our findings have important implications for policy makers and stakeholders involved in funding and commercializing AI R&D, for both public and private organizations, as well as for researchers interested in the role of government in fostering innovation. By providing a detailed analysis of the AI patent landscape, we hope to contribute to the existing literature on government participation in AI innovation and to inform future policy and funding decisions in this rapidly evolving field.

2. Related Work

2.1. Role of government in fostering innovation

Governments play a critical role in driving innovation and technological advancement in a country. They can do so through various policies and initiatives that support research and development (R&D), such as funding programs, tax incentives, and regulatory frameworks (Zhang, Sun, Peng, Zhao, Chen and Huang (2022); Deleidi and Mazzucato (2021); Song, Sahut, Zhang, Tian and Hikkerova (2022); Mulligan, Lenihan, Doran and Roper (2022); Wang (2018); Corredoira, Goldfarb and Shi (2018); Huang, Zhang, Youtie, Porter and Wang (2016)) Governments can also directly engage in R&D activities through their own research institutions or by collaborating with private sector firms and academia.

Recent studies on the role of government funding in innovation have shown that government funding can be an important driver of innovation, responsible for actively shaping and creating markets and systems, not just fixing them (Mowery (2010); Mazzucato and Semieniuk (2017)). Different from the neoclassical view of the market, in which the government is a passive fixer of market failures (Arrow (1971); Nelson (1971); Bush (2020)), recent researches have shown that the government plays a role of an active participant in the innovation process by deciding the direction and incentives for innovation.

In terms of the role of governmental organizations in driving innovation, studies have shown that they can play a particularly important role in the early stages of technology development, when the risks and uncertainties are high (Mazzucato and Semieniuk (2017)). This is because governmental organizations often have a longer time horizon and a greater tolerance for risk than private sector firms, which enables them to invest in more speculative and risky projects (Zhang et al. (2022)). In addition, governmental organizations can act as a catalyst for innovation by creating enabling environments and providing infrastructure and resources that support the development and commercialization of new technologies (Zhang et al. (2022); Mulligan et al. (2022); Huang et al. (2016)).

For example, governments can fund basic research and early stage R&D projects, which can lead to the development of new technologies and ideas that may not be immediately attractive to private sector firms due to the high levels of uncertainty and risk involved (Mazzucato and Semieniuk (2017); Huang et al. (2016)). Governments can also provide infrastructure and resources such as research facilities, data sets, and equipment that may not be readily available to private sector firms or academia, which can facilitate the development and commercialization of new technologies (Deleidi and Mazzucato (2021)).

However, the role of governmental organizations in innovation is not without challenges. One of the main challenges is the need to balance the goals of driving innovation with the need to ensure efficiency and accountability (Mulligan et al. (2022)). Governments need to ensure that their policies and initiatives are aligned with the national innovation system and the needs of the economy, and that they are achieving the desired outcomes in terms of technological advancement and economic growth. In addition, governments need to consider how to effectively collaborate with private sector firms and academia in order to maximize the impact of their innovation efforts (Song et al. (2022); Mulligan et al. (2022); Deleidi and Mazzucato (2021))

Effective collaboration between governmental organizations and private sector firms can lead to the transfer of knowledge and technology, and can facilitate the commercialization of new technologies. Governments can also collaborate with academia to access research expertise and knowledge, and to facilitate the translation of research findings into practical applications.

It is also important for governments to consider the potential social and economic implications of new technologies, and to ensure that they are developed and deployed in a responsible and ethical manner (Mazzucato and Semieniuk (2017); Song et al. (2022)). Governments can play a role in regulating and governing the use of new technologies, and in addressing any potential negative impacts that may arise.

Nevertheless, the existing studies on the role of government in innovation have not focused on the direct participation of governmental organizations in innovation. Rather, they have largely focused on both direct and indirect participation together, which makes it difficult to differentiate between the two. In this study, we focus only on the direct participation of governmental organizations in innovation, and we aim to understand the specific trend and direction of direct participation, with a comparison to existing results on indirect participation. Also, we aim to analyze the specific fields and areas, and the underlying motivations and priorities of governmental organizations through their direct participation.

2.2. AI innovation

Artificial intelligence (AI) has been widely recognized as a general purpose technology (GPT), meaning that it has the potential to drive innovation and technological advancement across a wide range of industries and sectors (Crafts (2021); Trajtenberg (2019); Goldfarb, Taska and Teodoridis (2023)). AI is a rapidly evolving field that encompasses a range of technologies and techniques, including machine learning, nat-

ural language processing, and computer vision, among others. These technologies enable machines to perform tasks that are typically associated with human intelligence, such as learning, problem solving, and decision making (Trajtenberg (2019)).

One of the key features of AI as a GPT is its ability to enable the development of new methods of invention (IMI). IMI refers to the development of new methods and tools that enable the invention of new ideas and technologies, and is a key driver of innovation and technological advancement (Griliches (1957); Crafts (2021); Cockburn, Henderson and Stern (2018)). AI can be used to analyze large data sets and extract insights that can inform the development of new methods and tools, and can also be used to optimize and improve existing methods and processes, leading to increased efficiency and competitiveness (Cockburn et al. (2018)).

Recently, there has been an attempt to study the innovation in AI field, using patent data (Giczy, Pairolero and Toole (2022); Toole, Pairolero, Giczy, Forman, Pulliam, Such, Chaki, Orange, Homescu, Frumkin et al. (2020)). The literature on innovations in AI and patenting has focused on describing the trends and patterns in patenting activity in the AI field, and on identifying the key players and firms that are driving innovation in this field.

For example, Cockburn et al. (2018); Fujii and Managi (2018) found that patenting activity in the AI field has increased significantly in recent years, with major players in the tech industry filing a large number of patents related to machine learning, natural language processing, and other AI technologies. Tsay and Liu (2020); Fujii and Managi (2018) also found that patenting activity in the AI field has been highly concentrated among a small number of firms, with the top patent holders accounting for a significant share of the total patents filed. These findings suggest that patenting can play a significant role in shaping the direction and governance of AI development and deployment, as well as in shaping the competitive landscape of the industry.

While these studies have provided macroscopic overview in the AI innovation, rare studies have focused on the specific role of governmental organizations in AI innovation. Here, we focus on the AI innovations that are directly invented by governmental organizations to understand the role of governmental organizations in AI innovation.

2.3. Adoption of AI technologies by governmental organizations

Artificial intelligence (AI) technologies have the potential to significantly impact the way in which governmental organizations operate and deliver services to citizens. In recent years, there has been a growing interest in understanding the challenges and opportunities presented by AI for the public sector, and in exploring the role of governmental organizations in driving the development and adoption of AI (van Noordt and Misuraca (2022); Gesk and Leyer (2022); de Sousa, de Melo, Bermejo, Farias and Gomes (2019); Chen, Guo, Gao and Liang (2021); Aoki (2020)).

A number of studies have focused on the use of AI by governmental organizations to support decision making and policy development. For example, van Noordt and Misuraca (2022) examined the use of AI to support the development of public policy in the European Union, and found that AI could be used to analyze large amounts of data and extract insights that can inform policy making. Other studies have examined the use of AI to improve the efficiency and effectiveness of public sector operations, such as through the automation of routine tasks or the use of AI to improve the delivery of public services (Pencheva, Esteve and Mikhaylov (2020); Kankanhalli, Charalabidis and Mellouli (2019); Mehr, Ash and Fellow (2017); Chen et al. (2021); Sun and Medaglia (2019))

However, there have also been a number of concerns raised about the adoption of AI by governmental organizations. One key issue has been the potential for AI to perpetuate existing biases and inequalities (Janssen et al. (2020); Giest and Samuels (2020); Bolukbasi, Chang, Zou, Saligrama and Kalai (2016)), particularly if the data used to train AI systems is biased or if the algorithms used are not transparent or explainable (Janssen et al. (2020); Giest and Samuels (2020)). There have also been concerns about the potential for AI to disrupt existing public sector jobs and industries and about the need for appropriate safeguards and regulation to ensure the responsible development and deployment of AI (Peeters and Widlak (2018); Brynjolfsson and Mitchell (2017); Frey and Osborne (2017); König and Wenzelburger (2020); Sun and Medaglia (2019)).

While the adoption of AI by governmental organizations has been emphasized as a key factor in shaping the future direction of AI development and deployment, there has not been much research specifically focused on the invention of AI technologies by governmental organizations. Thus, our focus in this area would be valuable in order to better understand the role of governmental organizations in driving innovation in the field of AI.

3. Materials and Methods

3.1. Data

Patent has been widely used as a proxy for innovation in the studies of innovation and policy (Corredoira et al. (2018); Furman, Porter and Stern (2002); Jaffe (2000); Liu, Shapira, Yue and Guan (2021)). Patents are legal documents that grant exclusive rights to inventors to prevent others from making, using, selling, or importing their invention for a limited period of time. In the process of publishing a patent, inventors must disclose the details of their invention in a public document, including the technical and functional features of the invention, as well as the problems it aims to solve. This information is then reviewed and assessed by patent examiners, who determine whether the invention meets the necessary criteria for a patent grant.

Hence, patent record have served as a useful indicator of technological progress and innovation, as they provide a comprehensive overview of the technical features and capabilities of an invention. They also provide insight into the problems and challenges that inventors aim to solve through

their innovations, as well as the potential impacts and applications of the invention.

Here, we utilize the Artificial Intelligence Patent Dataset (AIPD) dataset (Giczy et al. (2022); Toole et al. (2020)), which allows us to extract the AI-related patents. AIPD is a collection of US patents and pre-grant publications published between 1976 and 2020 that relate to various AI technology components, such as machine learning, natural language processing, computer vision, speech recognition, knowledge processing, AI hardware, evolutionary computation, and planning and control. This dataset was created using machine learning techniques to analyze the text and citations in patent documents to identify AI-related patents.

Then we limited our analysis to patents that were granted, as opposed to pre-grant patents, for following three reasons. First, granted patents have already undergone the patent examination process and have been determined to be novel, non-obvious, and useful, as required by patent laws. This means that granted patents are more likely to represent truly innovative technology than pre-grant patents, which have not yet been fully evaluated by the patent office (Liu et al. (2021)).

Second, granted patents are more likely to have been commercialized or used in some way, as the inventors or patent holders would have needed to demonstrate that the technology is useful in order to receive a grant. Pre-grant patents, on the other hand, may still be in the development stage and may not have been demonstrated to be useful or commercially viable yet.

Finally, granted patents are more likely to have a longer lifespan, as they typically have a 20-year term from the date of grant, while pre-grant patents may not be granted at all or may be granted with a shorter term. By focusing on granted patents, a study can potentially capture a longer time period of innovation.

After matching with *PatentsView*'s dataset for granted patents, 2,952,446 (granted) patents are left — regardless of their relations to AI — which accounts for 22.29% of all patents in AIPD dataset. Among them, 112,075 patents are predicted as AI-related patents by the algorithm in AIPD dataset (having the value 1 in the "predict_any_ai" column). Finally, to divide the patents into two groups based on the assignee information, we matched the patents with the assignee information from *PatentsView*, which results that 91,563 AI-related patents are left with their assignee information.

3.2. Patent embedding

To visualize the topological structure of AI-related patents, we vectorize words and documents using doc2vec to analyze a dataset of patent abstracts (Mikolov, Chen, Corrado and Dean (2013a); Mikolov, Sutskever, Chen, Corrado and Dean (2013b); Le and Mikolov (2014)). Doc2vec is a neural network model that learns to represent words and documents as continuous vectors in a low-dimensional space, capturing the semantic and syntactic relationships between them (Le and Mikolov (2014)).

We trained a doc2vec model on the patent abstract data, using the skip-gram architecture with negative sampling. The skip-gram architecture predicts context words based on a target word. Negative sampling randomly selects a small number of negative examples from the dataset to improve the model's efficiency. These negative examples are used to contrast with the positive examples, which helps the model to learn more robust representations of the words.

Once the doc2vec model was trained, we used it to generate word and document vectors for each word and documents — patent abstracts in our dataset — in the high dimensional embedding space. A word embedding is a continuous vector representation of a word, while a document embedding is a continuous vector representation of a document.

Using the assignee information, we divided the patent abstracts into two groups based on the employment status of the inventors: those invented having governmental organizations as assignee and those whose assignee is non-governmental organizations, such as corporations and academic institutions.

3.3. Extracting over-representative words

To identify the over-representative words in the patents in *AI-Pat-Gov* compared to *AI-Pat-Corp*, we used log-odds ratios with informative Dirichlet priors, which have been used in previous studies to identify over-representative words in text data(Monroe, Colaresi and Quinn (2008); Nakandala, Ciampaglia, Su and Ahn (2017)).

In this method, the log-odds ratio of each word w between two distinct groups of documents — patent abstracts, in our case — givent the prior frequencies calculated from a background corpus α is estimated, which represents a relative over-representativeness of a word. In particular, the log-odds ratio for word w, called $\delta_w^{(i-j)}$, is estimated as:

$$\delta_w^{(i-j)} = \log \frac{c_w^i + \alpha_w}{n^i + \alpha_0 - c_w^i + \alpha_w} - \log \frac{c_w^j + \alpha_w}{n^j + \alpha_0 - c_w^j + \alpha_w} \tag{1}$$

where c_w^i and c_w^j are the number of times word w appears in the documents in group i and j, respectively, n^i and n^j are the total number of words in the documents in group i and j, respectively, and α_0 and α_w are the size of the background corpus and the prior frequency of word w in the background corpus, respectively.

Then, the variance of the log-odds ratio is estimated as:

$$\sigma^2(\delta_w^{(i-j)}) \approx \frac{1}{c_w^i + \alpha_w} + \frac{1}{c_w^j + \alpha_w} \tag{2}$$

which allows us to obtain the z-score of the log-odds ratio as:

$$z(\delta_w^{(i-j)}) = \frac{\delta_w^{(i-j)}}{\sqrt{\sigma^2(\delta_w^{(i-j)})}} \tag{3}$$

Table 1
Number of total AI-related patents, AI-related patents invented by government organizations, and the percentage of AI-related patents by government organizations for each subcategory in AI technologies. The subcategories shown in the table include machine learning, evolutionary computation, natural language processing, speech recognition, computer vision, knowledge processing, planning and control, and AI hardware.

Subcategory	Total	*AI-Pat-Gov*	Percentage
Machine Learning	79,948	883	1.10
Evolutionary Computation	19,756	156	0.79
Natural Language Processing	67,870	170	0.25
Speech Recognition	40,477	134	0.33
Computer Vision	177,038	1,113	0.63
Knowledge Processing	353,529	2,006	0.57
Planning & Control	370,800	1,314	0.35
AI Hardware	223,760	821	0.37
All (Any AI)	642,956	3,052	0.47

We used this method to analyze the abstracts of AI-related patents, dividing the documents into two groups based on the type of assignee. The resulting log-odds ratios and informative Dirichlet priors allowed us to identify the words and topics that were most characteristic of each group, and to compare the content of AI patents between those invented by governmental organizations and those invented by non-governmental organizations.

4. Result

4.1. Trend of AI patents by government organizations

We first check how many AI-related patents have governmental organizations as their assignees, using descriptive statistics (Table 1). This table shows data on the number of total AI-related patents, the number of AI-related patents invented by government organizations, and the percentage of AI-related patents by government organizations for each subcategory in AI technologies. The subcategories shown in the table include machine learning, evolutionary computation, natural language processing, speech recognition, computer vision, knowledge processing, planning and control, and AI hardware.

It turns out that government organizations are the assignees of only a small portion of AI-related patents, compared to other institutions, such as private firms and academic institutions, while their AI-related patenting activity varies across subcategories. In particular, government organizations have a relatively high percentage of AI patents in the subcategories of machine learning, computer vision, and knowledge processing. For instance, government organizations hold 1.10% of the total AI patents in the machine learning subcategory, and 0.63% of the total AI patents in the computer vision subcategory.

It is also noteworthy that government organizations have a relatively low percentage of AI patents in the subcategories of natural language processing and speech recognition, with only 0.25% and 0.33% of the total patents in these subcategories, respectively. Since these subcategories are easier to commercialize than other subcategories, this indicates that government organizations are less active in the areas of AI research and development having higher applicability. In contrast, it is also possible to interpret the relatively lower participation of governmental organizations in these subcategories as a result of a higher proportion of patents held by non-governmental organizations due to their applicability.

The relative portions of subcategories in the total number of AI patents filed by governmental organizations also have changed over time. Figure 1 presents the number of AI-related patents filed by governmental organizations from 1976 to 2020 for each subcategory.

Our results reveal a marked increase in the number of AI patents invented by governmental organizations over the study period, particularly in the knowledge processing, planning and control, computer vision, and AI hardware categories. These four subcategories have exhibited a consistent upward trend from the 1970s to the early 2000s. During the 2000s, the number of inventions by governmental organizations in these four subcategories remained stable until a steep increase in the early 2010s. The remaining subcategories also show an overall upward trend, albeit at a slower rate.

At the same time, the trend suggests that governmental organizations have been actively engaged in AI innovation even in the early stages of AI development in the 1970s, with a focus on various fields such as the four categories mentioned above. AI innovation by governmental organizations has also been steadily more active over time, with a notable acceleration in the 2010s.

4.2. Leading government organizations in AI innovation

Then, what are the top government organizations in terms of the number of AI patents? Since our dataset is from USPTO, do only US government organizations appear in the top list? We answer these questions by examining the top 10 government organizations, by counting the number of AI patents

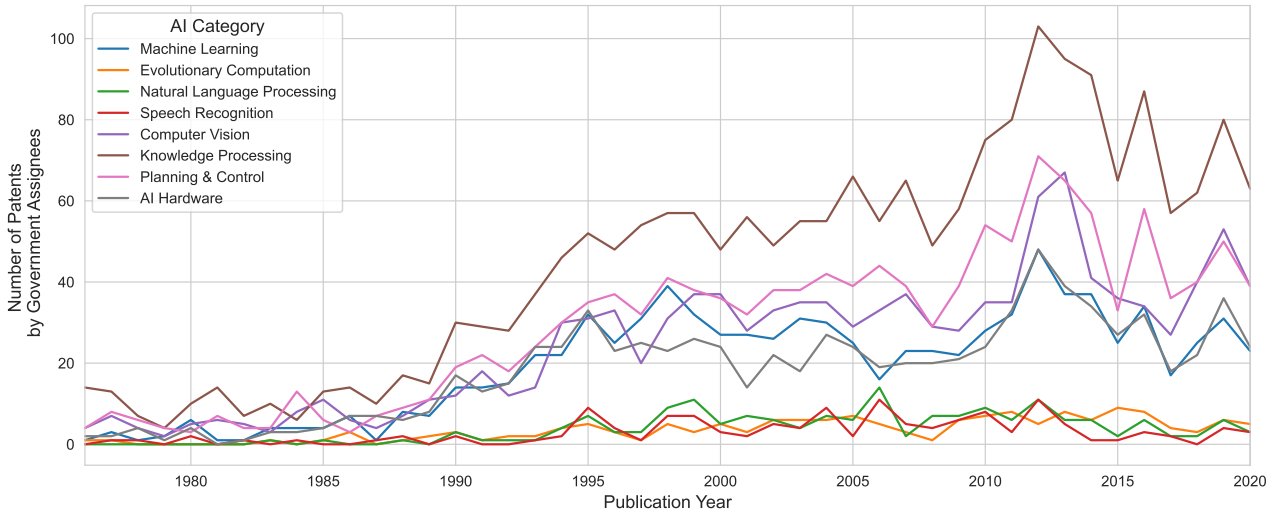

Figure 1: Number of AI-related patents filed by governmental organizations

Table 2
Top government organizations in terms of the number of AI patents, as well as the country in which each organization is based. The table includes information on the rank of each organization, the country, the name of the organization, and the number of AI patents held by the organization.

Rank	Country	Name	Number of AI Patents
1	USA	United States Navy	1,080
2	USA	United States Air Force	644
3	USA	United States National Aeronautics and Space Administration (NASA)	460
4	USA	United States Army	373
5	France	Commissariat a l'Energie Atomique (CEA)	124
6	USA	United States National Security Agency (NSA)	73
7	USA	United States Secretary of Agriculture	49
8	Canada	Minister of National Defence	43
9	Japan	Agency of Industrial Science and Technology	23
10	UK	State for Defence	20

held by each organization (Table 2). As shown in Table 2, the United States Navy has the largest number of artificial intelligence (AI) patents, with 1,080 patents, while the United States Air Force and the United States National Aeronautics and Space Administration (NASA) also have a significant number of AI patents, with 644 and 460 patents, respectively.

It is notable that government organizations in foreign countries also actively participate in obtaining AI-related patents from the United States Patent and Trademark Office (USPTO). France's Commissariat a l'Energie Atomique (CEA) has the fifth-highest number of AI patents among government organizations, with 124 patents. Japan's Agency of Industrial Science and Technology has the ninth-highest number of AI patents, with 23 patents. The United Kingdom's State for Defence has the tenth-highest number of AI patents, with 20 patents.

This result allows us to understand the direction of AI innovation in developed countries, as well as the role that these government organizations play in driving that innovation. In the United States, the top three organizations with the most AI patents are the United States Navy, the United States Air Force, and NASA. These organizations are responsible for military and space-related research and development, and it is likely that their AI patents are related to these areas. For instance, the Navy and Air Force may be using AI for tasks such as intelligence gathering, logistics, and aircraft navigation, while NASA may be using AI for tasks such as analyzing data from space missions or predicting the weather on other planets.

In France, the top organization with the most AI patents is the Commissariat a l'Energie Atomique (CEA), which is a government-funded research organization focused on nuclear and renewable energy, defense, and information technology. It is likely that the CEA's AI patents are related to these areas of research.

Meanwhile, in Japan, the top organization with the most AI patents is the Agency of Industrial Science and Technol-

ogy, which is a government agency responsible for promoting industrial technology and innovation. It is likely that the Agency's AI patents are related to improving industrial processes or developing new products and services.

In the United Kingdom, on the other hand, the top organization with the most AI patents is the State for Defence, which is responsible for the country's military defense. It is likely that the State's AI patents are related to military applications of AI, such as intelligence gathering or logistics.

The list of the top government organizations inventing new technologies are different from the top government organizations funding new technologies, found by existing studies (Corredoira et al. (2018); Zhang et al. (2022)). This is because the funding of AI patents and the invention of AI patents are two distinct activities, and organizations that excel at one may not necessarily excel at the other. Previous studies focusing on government organizations funding AI patents, rather than inventing them, show that the top government organizations include organizations that provide financial support for AI research and development, but do not necessarily have a direct role in the creation of the patented technology (Corredoira et al. (2018); Zhang et al. (2022); Mulligan et al. (2022); Song et al. (2022)).

On the other hand, because we focus of the study was on government organizations "inventing" AI patents, the top 10 list mostly consists of organizations that are directly involved in the research and development of AI technologies, and have a strong track record of creating and patenting new AI innovations. These organizations might include research labs or institutes dedicated to developing AI technologies for a variety of applications, or divisions within larger organizations, such as military or space agencies, that focus on AI research.

In this perspective, the main R&D focus of these organizations is aligned with that of the "mission-oriented" R&D spending of a group of industrial economies, such as defense, agriculture, health, energy, and other activities (Mowery (2010)). If we separate the R&D spending of government into "mission-oriented" and "nonmission-oriented", the top organizations for "inventing" strongly coincide with the leading governmental organizations "mission-oriented" R&D spending.

4.3. Focus of governmental organizations

By comparing the top 10 WIPO Technology classes for AI-related patents invented by all institutions and by governmental organizations, we can understand the focus of AI innovation by governmental organizations, which is different from that of non-governmental organizations due to their public roles. Table 3 provides lists the top 10 World Intellectual Property Organization (WIPO) Technology classes for AI-related patents invented by all institutions and by governmental organizations. The top 10 classes for all institutions and for governmental organizations are largely similar, with some classes appearing in both lists and others being unique to one list or the other.

One significant difference between the two lists is the specific classes that are included. While both lists include classes related to computer technology, digital communication, and IT methods for management, the list for governmental organizations also includes classes related to measurement, control, and medical technology. This suggests that the focus of AI innovation by governmental organizations is more closely aligned with fundamental technologies that are used in a variety of applications, rather than practical applications, which is easier to commercialize. For instance, the measurement and control class includes technologies related to sensors, which are used in a variety of applications, such as medical devices, industrial equipment, and consumer electronics.

Recent studies have discusseed AI technologies as both a general-purpose technology (GPT) and the inventionn of a method of invention (IMI) (Cockburn et al. (2018); Trajtenberg (2019); Crafts (2021); Goldfarb et al. (2023)). IMIs refer to the development of new methods or techniques for creating or discovering new knowledge, rather than the application or exploitation of existing knowledge, and they are a key driver of technological advancement and can have significant impact on the direction and pace of innovation. (Griliches (1957)). Our result implies that governmental organizations more focused on GPT- and IMI-type innovations even in the AI technologies, given their mandate to support and facilitate the advancement of science and technology for the public good (Mazzucato and Semieniuk (2017))

On the other hand, while commercialization — refering to the process of bringing a new product or service to market for the purpose of generating revenue — is a necessary step for many innovations to reach their full potential and have practical impact, it may not always be the primary focus of governmental organizations. The focus of governmental organizations on IMI-type innovations can be interpreted as their desire to support and advance the broader field of AI, rather than solely by the pursuit of economic gain (Mazzucato and Semieniuk (2017)).

Then, how are government organizations trying to apply specific AI technologies to different technological fields? In the landscape of AI technologies driven by governmental organizations, how are different types of AI technologies linked to other technological fields? To answer these qustions, we link the AI categories to the top 10 WIPO technology classes in Table 3, for the AI patents invented by governmental organizations. The Sankey diagram in Figure 2 show that there is a diverse range of linkages between AI categories and top WIPO technologies in the AI-related patents invented by governmental organizations.

It is notable that certain AI categories, such as Knowledge Processing and Computer Vision, appear across a wide range of WIPO technologies. This suggests that these AI categories are particularly relevant and applicable to a broad range of technological fields, and that governmental organizations are actively involved in their development and application.

On the other hand, other AI categories — such as AI Hardware and Natural Language Processing, are more closely

Table 3
Top 10 World Intellectual Property Organization (WIPO) Technology classes for the AI-related patents invented by all and by governmental organizations

Rank	WIPO Category for All	Number of Patents	WIPO Category for Governmental Organizations	Number of Patents
1	Computer technology	359,676	Computer technology	1,180
2	Digital communication	132,988	Measurement	913
3	IT methods for management	93,408	Control	264
4	Measurement	55,449	Medical technology	214
5	Audio-visual technology	54,165	Audio-visual technology	173
6	Control	50,707	Digital communication	158
7	Telecommunications	46,267	Other special machines	141
8	Medical technology	41,449	IT methods for management	127
9	Transport	15,101	Telecommunications	121
10	Optics	13,242	Biotechnology	115

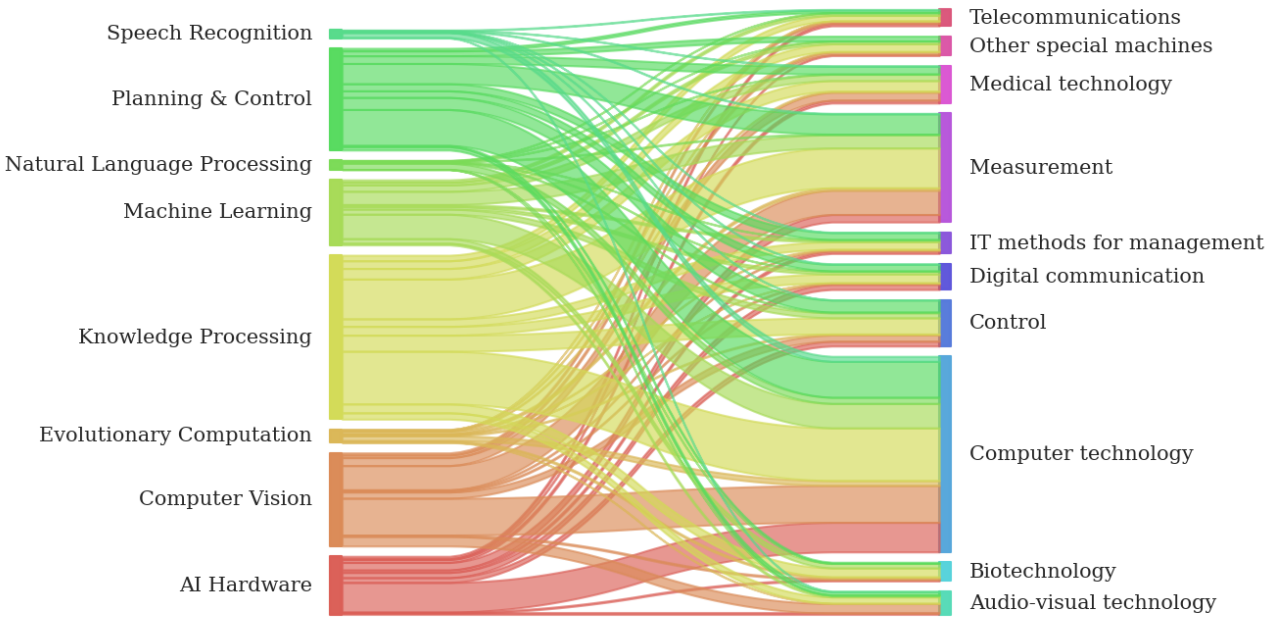

Figure 2: Sankey diagram showing the flow of AI-related patents from governmental organizations to WIPO technology classes

linked to specific WIPO technologies. For example, AI Hardware is particularly closely linked to Computer technology, while Natural Language Processing is closely linked to Digital communication, which shows that these AI categories are more specialized and focused on specific technological fields, and that governmental organizations are particularly active in their development and application within these fields.

4.4. Over-represented words in AI-related patents by governmental organizations

Although the linkages between AI categories and WIPO technologies provide a general overview of the landscape of AI technologies driven by governmental organizations, it does not provide a detailed understanding of the context in which these AI technologies are applied. To better understand the contextual differences between the AI-related patents invented by governmental organizations and those invented by non-governmental organizations, we matched the AI-related patents invented by governmental organizations with the most similar AI-related patents but invented by non-governmental organizations based on their AI subcategories, WIPO titles, and abstracts, as explained in Section 3.2 and 3.3 in detail. Figure 3 shows the over-represented words in the AI-related patents invented by governmental organizations and those invented by non-governmental organizations, based on the z-score of the word frequencies between the matched similar patents.

The results presented in Figure 3 reveal clear differences between the language used in AI patent abstracts invented by governmental organizations and those invented by non-

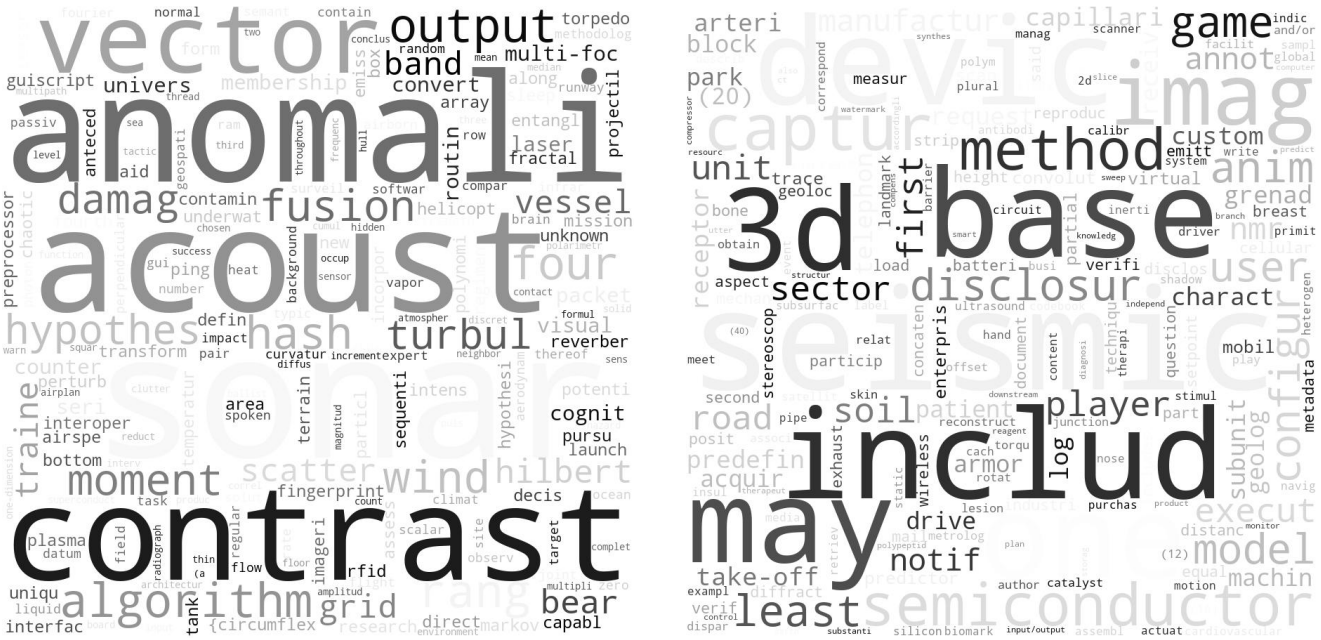

Figure 3: Wordcloud visualizations of the over-represented words in the AI-related patents invented by governmental organizations (left) and non-governmental organizations (right)

governmental organizations. The over-represented words in the AI patent abstracts invented by governmental organizations include terms related to sonar, acoustics, and anomaly detection, as well as words related to algorithms and data output. In contrast, the over-represented words in the AI patent abstracts invented by non-governmental organizations include terms related to the capture of 3D images and the use of semiconductor devices, as well as words associated with games and animation. In contrast, the over-represented words in the AI patent abstracts invented by governmental organizations include terms related to sonar, acoustics, and anomaly detection, as well as words related to algorithms and data output.

The differences in language use show that governmental organizations are more focused on the development of AI technologies for defense and security applications, such as the detection of anomalies in sonar data or the use of algorithms to analyze and interpret data from sensors. On the other hand, non-governmental organizations are more focused on the development of AI technologies for commercial applications, such as the creation of immersive gaming experiences or the use of 3D imaging in consumer devices.

The significant contrast between the abstracts of AI patents invented by governmental organizations and those invented by non-governmental organizations highlights the diverse and complex roles that governmental organizations play in the field of AI innovation. While non-governmental organizations may be more focused on the development of AI technologies for commercial purposes, governmental organizations appear to be more focused on the development of AI technologies for defense and security applications. This underscores the importance of considering the role of governmental organizations in the broader landscape of AI innovation, as they play a critical role in shaping the direction and impact of AI technologies on society.

5. Conclusion

Governmental organizations have a significant role to play in driving innovation and technological advancement in a country. By providing funding, resources, and enabling environments, and by collaborating with private sector firms and academia, governments can support the development and commercialization of new technologies and ideas, and contribute to the overall growth and competitiveness of the national innovation system. However, the role of governmental organizations in AI innovation by directly participating in the invention of AI technologies still has not been well understood.

Here, we have analyzed the AI-related patents invented by governmental organizations in the United States and compared them to those invented by non-governmental organizations. We found that governmental organizations are more likely to invent AI technologies that are more fundamental and less likely to be directly commercialized. This is due to the public role of governmental organizations in promoting the technological advancement of the country, and may have implications for the direction and impact of AI innovation.

Also, our result reveals that governmental organizations have a diverse focus in terms of the technological fields and AI technologies in which they are involved in patent invention. This diversity reflects the wide-ranging interests and capabilities of governmental organizations in the field of AI, as well as their role in driving technological advancement and innovation in society.

Our study still has several limitations. First, we only ana-

lyzed the AI-related patents as a case study to understand the role of governmental organizations in innovation process, and our results may not be generalizable to other technologies. However, while considering various technologies in our anlysis may help us to generalize our results, it makes impossible to compare the trend and direction by governmental organizations with that non-governmental organizations, due to the simultaneous and parallel development of different technologies. Our focus on AI technologies is, on the other hand, allows us to extract the diffrences in the role of governmental organizations in the development of AI technologies.

Second, we only analyzed the AI-related patents in the United States, which cannot guarantee that our results can be generalizable to other countries, although our results include foreign governmental organizations as well. In the future, further research expanding our analysis to other countries and to other technologies can help us better understand the direct role of governmental organizations, in addition to their role in supporting and facilitating the development of AI technologies by other actors.

Despite these drawbacks, this study offers the first and only original analysis of the AI patents developed directly by governmental organizations in the United States, with a specific focus on the its role and direction considering different core governance functions in national innovation system. Since government begin to apply AI technologies to a variety of tasks, it is necessary to have a clear understanding of the various incentives and approaches for each governance function. This can be done through the interaction with potential additional drivers, barriers, consequences, and risks for each stage of innovation. This is an important contribution for academics and decision-makers to better comprehend the possible effects of AI for the public sector in the United States.

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