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The current scenario of Artificial Intelligence development in Brazil

Mapping Artificial Intelligence centers in Brazil: Initiatives, actions, and projects

By Rodrigo Brandão

Currently, different countries and territories have been promoting the development of Artificial Intelligence (AI), guided by the understanding that this technology is a valuable asset in tackling domestic challenges, accelerating economic growth and consolidating strategic geopolitical positions. In the case of Brazil, one of the main initiatives to this end is the creation of Engineering Research Centers/ Applied Research Centers (CPE/CPA)[1] in AI by the Research Foundation of the State of São Paulo (Fapesp), especially in the context of a collaboration signed with the Ministry of Science, Technology and Innovation (MCTI), the Ministry of Communications (MC) and the Brazilian Internet Steering Committee (CGI.br). This article maps the existing AI CPE/CPA across Brazil, the context in which they were created and their current standing, and points out the challenges they face relating to their institutional consolidation.

Institutional context

Nowadays, in the process of being revised, the Brazilian AI Strategy (EBIA)[2] envisages — in its original formulation — a set of 73 strategic actions aimed at developing AI in Brazil, divided into vertical and horizontal axes (Figure 1). The implementation of these actions is the responsibility of the EBIA Governance Committee, which is assisted by nine thematic subcommittees.

[1] Find out more: https://bv.fapesp.br/en/604/engineering-research-centersapplied-research-centers-cpecpa/

[2] EBIA was established by MCTI Ordinance No. 4.617, of April 6, 2021, amended by MCTI Ordinance No. 4.979, of July 13, 2021. In December 2023, the MCTI began a process to revise the EBIA, which is expected to be completed by May 2024 (MCTI, 2023).

Photo: Personal archive

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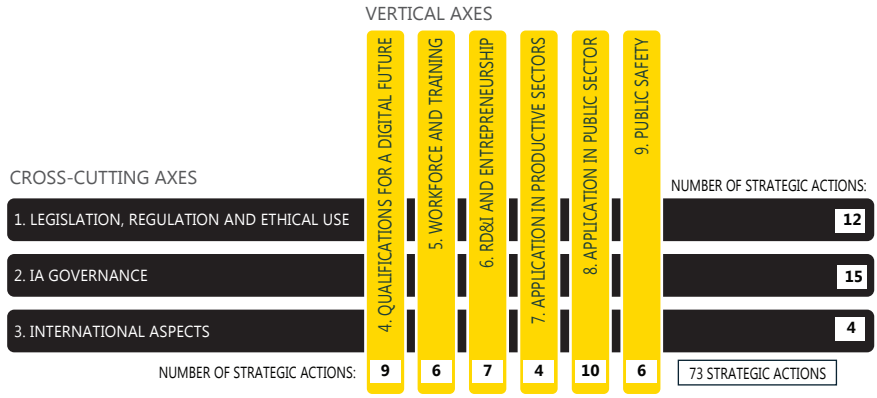
Figure 1 – GENERAL STRUCTURE OF EBIA



Source: MCTI (n.d.-c).

Over time, the agency began to prioritize some of the 73 strategic actions, aiming to narrow down the focus of each axis. In some cases, the change was significant. An example is Axis 2 ("AI Governance"). Out of its 15 strategic actions, one has been prioritized, namely, "Create an Artificial Intelligence observatory in Brazil that can connect to other international observatories"[3] (MCTI, n.d.-a). In Axis 6 ("R&D and Entrepreneurship"), the seven initial strategic actions were reorganized around three priority initiatives, which, to be implemented, rely directly or indirectly on the establishment of CPE/CPA in AI.

General characteristics of the centers

One of Fapesp's programs is the establishment of CPE/CPA, which operates through calls. Inspired by Research, Innovation, and Dissemination Centers (RIDC) and Research in Partnership for Technological Innovation (PITE) programs — both from Fapesp itself —, the CPE/CPA initiative aims to foster closer collaboration between companies and research institutions. The program anticipates that companies will not only co-finance research but also contribute to defining the focal themes for investigation, actively engage in research activities, and utilize the obtained results (Fapesp, n.d.-a). Through this approach, the institution facilitates the financing of knowledge production devoted to solving specific challenges.

[3] The implementation of this initiative is discussed in this edition of the Internet Sectoral Overview (ISO), in an interview with Luiz Alexandre Reali Costa, manager of the Brazilian Observatory of Artificial Intelligence (OBIA).

In 2019, Fapesp published the *IBM-Fapesp Artificial Intelligence Engineering Research Center*[4] call, in partnership with the International Business Machines Corporation (IBM) (Fapesp, 2019a), and the *Fapesp – MCTIC – CGI.br Call for Proposals for Applied Research Centers in Artificial Intelligence*.[5] The first of these culminated in the creation of the Center for Artificial Intelligence (C4AI), based at the University of São Paulo (USP). The second call planned the selection of four proposals, but six were chosen due to their quality. In 2021, Fapesp held a second call in partnership with MCTI and CGI.br, which also involved MC's participation.[6] As with the previous call, the number of approved centers exceeded the initially anticipated: In September 2023, the creation of four additional CPE/CPA was announced, instead of just two as originally planned in the call. Therefore, Brazil currently has 11 CPE/CPA in AI created by Fapesp: One in a partnership with IBM, and ten in a partnership with MCTI-MC and CGI.br. The interview with professor Fábio Cozman in this issue of Internet Sectoral Overview (ISO) provides information about the C4AI USP-Fapesp-IBM. An overview of the other ten centers is provided below (Table 1), which is detailed at the end of this article (Section "An overview of the centers").

(...) Brazil currently has 11 CPE/CPA in AI created by Fapesp: One in a partnership with IBM, and ten in a partnership with MCTI-MC and CGI.br.

In relation to the centers, four observations are necessary. Firstly, many were created from ongoing projects; therefore, framing them as CPE/CPA served to strengthen the institutional and financial aspects of previously existing research efforts. The second observation is that, in general, funding for the centers selected in 2021 began in 2023. The centers selected in 2023, on the other hand, are still structuring themselves as CPE/CPA. Thirdly, of the ten centers, six are in the Southeast and four in the Northeast. Finally, "industry" and "health" are the focus areas of most of the centers; "cities", "agriculture" and "cybersecurity" are also addressed.

The calls for proposals were based on the state-of-the-art of AI in Brazil and worldwide. Subsequently, some data regarding five concerns present in the three documents are gathered: (a) expansion of public investments in AI; (b) internationalization of Brazilian production; (c) geographical deconcentration of national AI research; (d) dissemination of this technology; and (e) workforce training.

[4] Find out more: https://fapesp.br/12508/ibm-fapesp-engineering-research-center-in-artificial-inteligence
[5] Find out more: https://fapesp.br/cpe/chamada_de_propostas_fapesp_%E2%80%93_mctic_-_cgi.br_para_centros_de_pesquisas_aplicadas_em_inteligencia_artificial/20-e
[6] Find out more: https://fapesp.br/15116/chamada-de-propostas-fapesp-mcti-mc-cgibr-para-centros-de-pesquisa-aplicada-em-inteligencia-artificial-cpas-ia-2021

Table 1 – OVERVIEW OF THE FAPESP-MCTI-MC-CGI.BR AI CENTERS

Year of selection	Center	Host institution	Focus areas
2021	Artificial Intelligence in the Remaking of Urban Environments (IARA)[7]	Institute of Mathematical and Computer Sciences (ICMC) at the University of São Paulo	Cities
2021	Brazilian Institute of Data Science (BIOS)[8]	Faculty of Electrical and Computer Engineering (FEEC) of the State University of Campinas (Unicamp)	Health and Agriculture
2021	Center of Excellence in Applied Research in Artificial Intelligence for Industry[9]	Faculty of Technology of the SENAI CIMATEC University Center	Industry
2021	Center for Applied Research in Artificial Intelligence for the Evolution of Industries to Standard 4.0[10]	Technological Research Institute (IPT) of the State of São Paulo	Industry
2021	Innovation Center on Artificial Intelligence for Health (CIIA-Health)[11]	Institute of Exact Sciences (ICEx) of the Federal University of Minas Gerais (UFMG)	Health
2021	Reference Center on Artificial Intelligence (CEREIA)[12]	The rector's office of the Federal University of Ceará (UFC)	Health
2023	Engineering Research Center Data Science for Intelligent Industry (CDI2)	ICMC-USP; Institute of Computing (IC) at Unicamp; Department of Computing at São Paulo State University (Unesp) at Bauru; and Advanced Institute for Artificial Intelligence (AI2) at Unesp	Industry (training)
2023	Center of Excellence in Artificial Intelligence for Renewable Energies	Alberto Luiz Coimbra Institute of Graduate Studies and Research in Engineering (Coppe) at the Federal University of Rio de Janeiro (UFRJ))	Industry (renewable energies)
2023	Center of Excellence in Artificial Intelligence for Cybersecurity	Information Technology Center (CIn) at the Federal University of Pernambuco (UFPE)	Cybersecurity
2023	Center for Really Applied Research in Artificial Intelligence: Education for the 4th Industrial Revolution (PRAIA Education)	Cin-UFPE	Industry (training)

Source: Prepared by the author, based on MCTI (s.d.-b) and Agência Fapesp (2023).

[7] Find out more: https://bv.fapesp.br/en/auxilios/111390/iara-artificial-intelligence-in-the-remaking-of-urban-environments/
[8] Find out more: https://bv.fapesp.br/en/auxilios/109243/bi0s-brazilian-institute-of-data-science/
[9] Find out more: https://bv.fapesp.br/en/auxilios/111046/center-of-excellence-in-applied-research-in-artificial-intelligence-for-industry/
[10] Find out more: https://bv.fapesp.br/en/auxilios/110902/center-for-applied-research-in-artificial-intelligence-for-the-evolution-of-industries-to-standard-4/
[11] Find out more: https://bv.fapesp.br/en/auxilios/110077/artificial-intelligence-innovation-center-for-health-ciia-health/
[12] Find out more: https://bv.fapesp.br/en/auxilios/109947/cereia-reference-center-on-artificial-intelligence/

Regarding the first topic, it is worth noting that, collectively, the 11 CPE/CPA in AI will involve public and private investiments of approximately R$ 240 million over ten years (R$ 4 million annually in C4AI, excluding contributions from USP, and about R$ 2 million in each of the ten Fapesp-MCTI-MC-CGI.br CPE/CPA, excluding contributions from each of the host institutions). For comparison, the United States intends to invest up to US$ 360 million by 2025 in the creation of 18 AI centers distributed among 40 states (National Science Foundation [NSF], 2021), while Canada has allocated C$ 125 million for the creation or strengthening of three centers (Canada Newswire [CNW], 2017). Australia is set to invest nearly AU$ 54 million in the establishment of its "National Artificial Intelligence (AI) Centre", accompanied by four "Digital and AI Capability Centres" (Australian Government, 2021), whereas France announced, for the period 2019-2023, investments of € 225 million in four similar centers to those in Brazil (Organization for Economic Co-operation and Development [OECD], n.d.).

The resources allocated to the CPE/CPA can help to expand Brazilian AI production, contributing to keeping the country among the top 20 countries or territories with the highest volume of academic publications in the field. Brazil was part of this group during the periods of 2014-2018 and 2019-2023 (Tables 2 and 3).[13] However, the comparison between the two analyzed periods suggests that the "momentum" of national AI research decreased compared to other countries or territories, even though — in absolute numbers — it increased. On the other hand, the requirement in the calls for proposals for CPE/CPA to have international connections can make Brazilian production more strategic on a global level. Between 2019 and 2023, Brazil was far from the countries that presented the most scientific papers at one of the main academic conferences on AI, the Association for the Advancement of Artificial Intelligence (AAAI) Conference on Artificial Intelligence (Table 4).

(...) the 11 CPE/CPA in AI will involve public and private investments of approximately R$ 240 million over ten years (...).

[13] Tables 2, 3, 4, and 5 were constructed using the Scopus database, which is owned by Elsevier. The search used the following parameters: (a) title, abstract, keywords ("artificial intelligence"); (b) year ("2019", "2020", "2021", "2022", "2023"); (c) publication stage ("final"); and (d) document types ("conference paper", "article", "review"). More precisely, the following parameters were used in "Advanced Search": TITLE-ABS-KEY ("artificial intelligence") AND PUBYEAR > 1990 AND PUBYEAR < 2024 AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re"))

Table 2 – NUMBER OF DOCUMENTS ON AI, BY COUNTRY OR TERRITORY[14] (2014-2018)

Position	Country or territory	Number of documents
1	United States	20,973
2	China	17,456
3	India	9,378
4	United Kingdom	6,854
5	Germany	5,339
6	France	4,345
7	Japan	4,310
8	Italy	4,048
9	Spain	4,015
10	Canada	3,615
11	Australia	3,187
12	South Korea	2,343
13	**Brazil**	**2,202**
14	Poland	2,113
15	Russia	1,751
16	Netherlands	1,730
17	Taiwan	1,665
18	Iran	1,637
19	Turkey	1,523
20	Portugal	1,333

Source: Prepared by the author based on data from Scopus (Elsevier) (https://www.scopus.com/search/form.uri?display=basic#basic), consultation was carried out on March 13, 2024.

[14] A scientific document can be associated to more than one country.

Table 3 – NUMBER OF DOCUMENTS ON AI, BY COUNTRY OR TERRITORY (2019-2023)

Position	Country or territory	Number of documents
1	China	49,791
2	United States	33,298
3	India	20,449
4	United Kingdom	12,257
5	Germany	10,878
6	Italy	9,105
7	Canada	6,544
8	South Korea	6,440
9	Spain	6,174
10	France	5,932
11	Australia	5,854
12	Japan	5,332
13	Russia	4,827
14	Saudi Arabia	4,270
15	Netherlands	3,693
16	Taiwan	3,564
17	**Brazil**	**3,367**
18	Turkey	3,296
19	Iran	2,858
20	Malaysia	2,813

Source: Prepared by the author based on data from Scopus (Elsevier) (https://www.scopus.com/search/form.uri?display=basic#basic), consultation was carried out on March 13, 2024.

Table 4 – NUMBER OF DOCUMENTS IN THE AAAI CONFERENCE, BY COUNTRY OR TERRITORY (2019-2023)

Position	Country or territory	Number of documents
1	China	1,994
2	United States	1,649
3	United Kingdom	308
4	Australia	251
5	Singapore	233
6	Germany	210
7	Hong Kong	200
8	Canada	196
9	India	170
10	Japan	154
11	South Korea	154
12	Italy	119
13	France	105
14	Israel	104
15	Switzerland	73
16	Austria	61
17	Taiwan	50
18	Netherlands	47
19	Poland	41
20	Czech Republic	35
(...)		
30	**Brazil**	**17**

Source: Prepared by the author based on data from Scopus (Elsevier) (https://www.scopus.com/search/form.uri?display=basic#basic), consultation was carried out on March 8, 2024.

The concern of the Fapesp-MCTI-MC-CGI.br calls for proposals to create centers in different states can contribute to the geographical deconcentration of academic production and, consequently, to the formation of academic hubs in different regions of the country. The volume of recent Brazilian production on AI has been led by a group of universities in the state of São Paulo (Table 5).

Table 5 – NUMBER OF DOCUMENTS ON AI, BY BRAZILIAN INSTITUTION[15] (2019-2023)

Institution	Number of documents
University of São Paulo	479
University of Campinas	195
São Paulo State University	141
Federal University of Rio Grande do Sul	134
Federal University of Minas Gerais	134
Federal University of Rio de Janeiro	131
Federal University of Pernambuco	128
Federal University of São Paulo	118
University of Brasilia	111
Federal University of Paraná	87
Federal Technological University of Paraná	87
Federal Fluminense University	86
Federal University of Santa Catarina	82
Federal University of Ceará	81
Federal University of Goiás	72

Source: Prepared by the author based on data from Scopus (Elsevier) (https://www.scopus.com/search/form.uri?display=basic#basic), consultation was carried out on March 7, 2024.

Regarding the generation of startups or spin-offs that incorporate the results of research developed by CPE/CPA into their products or services, it is worth noting that Brazil lacks indicators on the social and economic diffusion of AI. Some clues to this phenomenon can be found in research conducted by the Regional Center for Studies on the Development of the Information Society (Cetic.br), a department of the Brazilian Network Information Center (NIC.br), linked to the Brazilian Internet Steering Committee (CGI.br).[16.]

[15] A scientific document can be associated with more than one institution.

[16] In recent editions, the ICT Enterprises, ICT Electronic-Government, and ICT Health surveys have provided information on the adoption of AI technologies by businesses, government agencies, and healthcare establishments, respectively. Meanwhile, the TIC Education survey has been presenting data on teaching activities related to the responsible and ethical development of various technologies, such as AI. Some of these data are compiled in the "Answers to your Questions" section of this issue of the ISO.

Finally, the concern about training skilled workers in AI — either to develop it or to use it — is echoed in the low number of graduates and doctoral degrees in computer science and engineering in Brazil compared to other countries. As recorded in the document *Recommendations for the advancement of artificial intelligence in Brazil* (prepared by the Brazilian Academy of Sciences [ABC] and republished in this issue of ISO), 2019 data from the Coordination for the Improvement of Higher Education Personnel (CAPES) indicate that "the number of doctors graduating annually in computing was below 400 in 2016 and is not expected to have increased during the COVID-19 pandemic" (ABC, 2023). In contrast, in the United States, the number of doctoral graduates in these two areas has remained around 1,800 in the last 11 years, and during this period, the quantity of doctoral graduates specialized in AI has increased from 10% to 19%.

An overview of the centers

This section presents a brief profile of each CPE/CPA selected in the two Fapesp-MCTI-MC-CGI.br calls, highlighting their main objective and lines of research. To gather this information, the researchers responsible for the centers were contacted between February and March 2024. The following profiles were created based on the adaptation of the responses received. In some cases, however, it was not possible to consult these individuals. For this reason, pieces of information available on the Internet were used.[17]

Box 1 – IARA[18]

General information

- **Areas of knowledge:** Exact and Earth Sciences; Computer Science; Computer Methodology and Techniques
- **Subject(s):** Computational learning; smart cities; AI; Internet of Things (IoT)
- **Researcher in charge:** André Carlos Ponce de Leon Ferreira de Carvalho
- **Host institution:** ICMC-USP
- **Municipality/state:** São Carlos/São Paulo

At the time of the first Fapesp-MCTI-MC-CGI.br call for proposals, a project supported by the Research, Innovation and Dissemination Centers (CEPID) program, the Center for Mathematical Sciences Applied to Industry (CeMEAI), sought to create a network of smart cities, with the city of Canaã dos Carajás (Pará) as its starting point. The announcement of the creation of the CPE/CPA in AI served

[17] It should also be noted that Fapesp's Virtual Library has a page dedicated to each of the six CPE/CPA selected in 2021.
[18] Find out more: https://bv.fapesp.br/en/auxilios/111390/iara-artificial-intelligence-in-the-remaking-of-urban-environments/

as an opportunity to integrate the scientific efforts made in this field with the research of a group of AI researchers who were working on different applications, many with social contributions. From this collaboration, emerged the IARA center, with the mission of transforming environments, at different technological and social levels, through technological tools allied to social policies, so that they offer better services to their population. This transformation seeks to meet the Sustainable Development Goals (SDG) defined by the United Nations (UN), making these environments places where services are efficiently and effectively provided.

Guided by this mission, the IARA center has taken on the primary objective of generating research and applied solutions based on AI to not only transform conventional cities into smart cities, but also to continuously enhance smart cities, improving the quality of life of their inhabitants. Professor André Ponce de Leon notes that achieving this goal depends on fulfilling specific objectives, such as carrying out basic research that will serve as support for applied research and developing computer tools to implement the applications required to make urban environments intelligent. To meet these objectives, the center explores two lines of research related to cities: (a) infrastructure, which encompasses water and sanitation, energy, the environment, mobility and telecommunications; and (b) applications, which includes agriculture, culture, social development, education, sports and leisure, health, security and tourism.

In addition to contributing to the advancement of research into smart cities, the center aims to achieve four other results over the next five years: (a) serve at least 20 Brazilian cities; (b) having the inteli.gente Platform, a digital tool provided by the MCTI, supporting public policies in Brazilian cities; (c) develop at least 40 projects with the companies that participate in the center; and (d) train at least 100 new researchers in the subject.

Box 2 – BI0S[19]

General information

- **Areas of knowledge:** Interdisciplinary
- **Subject(s): AI;** computational learning; image processing; precision agriculture; obstetrics; women's health; research institutes
- **Researcher in charge:** João Marcos Travassos Romano
- **Host institution:** FEEC-UNICAMP
- **Municipality/state:** Campinas/São Paulo

BI0S aspires to be a leader in the country's digital transformation, contributing to the expansion of the applied frontier of AI and fostering a data culture within Brazilian organizations, through training and generating high value-added businesses. To fulfill this mission, the center is committed to developing work in two research lines: Health (primary track) and agriculture (secondary track).

[19] Find out more: https://bv.fapesp.br/en/auxilios/109243/bi0s-brazilian-institute-of-data-science/

Professor João Marcos Travassos Romano notes that, in the health track, the focus will be on tackling problems associated with women's health at the various stages of their life cycle. In the first stage, the main problems addressed will be maternal and neonatal mortality and the early mortality of women from preventable and potentially curable diseases, such as colon cancer and breast cancer. In the agriculture track, the main objective is to increase the availability and quality of useful information for decision-making in agriculture, both at the local, regional, or even global scale, with solutions for precision agriculture, also addressing issues such as the impacts of climate change.

BIOS also has a methodology track, aimed at supporting application fronts with AI tools, as well as addressing issues dear to society regarding the proper and ethical use of AI tools. Finally, it is worth noting that working on two thematic tracks positions BIOS as a center capable of tackling cross-cutting problems of great current interest, which are at the forefront between the health and agriculture tracks, such as the relationships between a particular cultivation strategy and its effects on human health.

Box 3 – CENTER OF EXCELLENCE IN APPLIED RESEARCH IN ARTIFICIAL INTELLIGENCE FOR INDUSTRY[20]

General information

- **Areas of expertise:** Exact and Earth Sciences; Computer Science
- **Subject(s):** AI; research institutes; applied research; industries
- **Researcher in charge:** Davidson Martins Moreira
- **Host institution:** Faculty of Technology of the SENAI CIMATEC University Center
- **Municipality/state:** Salvador/Bahia

The center is focused on developing a digital, open and multi-user data science and AI platform, focused on solving problems in various industry verticals (I-AI).Thus contributing to the development, leverage and modernization of Brazilian industry in order to meet the continuously evolving standards of Industry 4.0. More precisely, according to Professor Davidson Martins Moreira, the center will act as a facilitator, identifying and helping to build AI solutions for companies, and the platform will be the means to this end. He further notes that, unlike proprietary platforms, this platform will be owned by the Brazilian government, allowing micro, small, and medium-sized enterprises access to tools capable of accelerating their innovation and smart manufacturing processes. It can also be incorporated by private companies into their own computing infrastructure.

[20] Find out more: https://bv.fapesp.br/en/auxilios/111046/center-of-excellence-in-applied-research-in-artificial-intelligence-for-industry/

The platform will allow its functionalities, resources and architecture to be enhanced and expanded for specific solutions with greater impact for each industrial segment, offering, for example, applications in the areas of: Predictive maintenance for oil platforms, integration and optimization of production plant processes, intelligent monitoring of mines and dams, asset management, digital twins, among others. The platform will also serve as an enabling agent for integrated network projects, as it will make it easier for researchers, companies, startups and students to access data, models and acceleration tools. Finally, it will enable applications to be scaled up and can be used as a shared environment for experiments and training, fostering and accelerating the adoption of AI in enterprises.

The center explores eight research lines: Computer vision; natural language processing; time series; optimization of industrial processes; edging processing (IoT); distributed storage; pattern recognition; and virtualization of industrial environments. Among these research lines, the platform will initially focus on those that relate to the interests of the industry and academic partners who will support the center's development.

Box 4 – CENTER FOR APPLIED RESEARCH IN ARTIFICIAL INTELLIGENCE FOR THE EVOLUTION OF INDUSTRIES TO STANDARD 4.0[21]

General information

- **Areas of knowledge:** Interdisciplinary
- **Subject(s):** Robotics; AI; interoperability; real-time control; digital twin; industry 4.0
- **Researcher in charge:** Jefferson de Oliveira Gomes
- **Host institution:** IPT
- **Municipality/state:** São Paulo/São Paulo

The center explores six lines of research: Real-time monitoring and control; digital twin; interoperability and chain integration; prescriptive maintenance and intelligent operation; autonomous systems, robotics, and machine tools; and cybersecurity. Based on the development of projects on these fronts, the center's main objective is to "structure an AI Platform to enable the acceleration and digitalization of Brazilian industry, through the application of state-of-the-art technology focused on meeting industry needs, conducting out R&D and proofs of concept and implementing concepts in demonstration plants" (Fapesp, n.d.).

[21] The center is also known as the IAsmin Platform - The Evolution of Brazilian Industry to Standard 4.0. Find out more: https://bv.fapesp.br/en/auxilios/110902/center-for-applied-research-in-artificial-intelligence-for-the-evolution-of-industries-to-standard-4/ and https://plataformaiasmin.org.br/

Box 5 – CIIA-HEALTH[22]

General information

- **Areas of knowledge:** Interdisciplinary
- **Subject(s):** Algorithms; computational learning; deep learning; AI; neural networks (computing); reliability; models; optimization; prediction; simulation; usability; diagnosis; health information management; epidemics; quality of life
- **Researcher in charge:** Virgilio Augusto Fernandes Almeida
- **Host institution:** ICEx-UFMG
- **Municipality/state:** Belo Horizonte/Minas Gerais

The center's main objective is to research and develop advanced AI solutions,

> [...] to assist doctors and health professionals in the diagnosis and treatment of diseases and health managers in the organization of preventive health care actions to optimize the use of resources and improve the health of the population in Brazil. (CIIA-Health, n.d., para. 1)

To this end, the center develops work in four lines of research: Ethics and human values; models and algorithms; data management and engineering; and computer systems. Currently, researchers affiliated with CIIA-Health are involved in at least seven distinct projects: Prevention of chronic diseases; telemonitoring and mobile technologies; AI-guided diagnosis; personalized medicine in oncology; AI-guided surgery; prevention and mitigation of epidemics; and SUS's databases integration and supplementary health.

Box 6 – CEREIA[23]

General information

- **Areas of knowledge:** Interdisciplinary
- **Subject(s):** Data science; AI; technology transfer; precision medicine; healthcare; healthcare technologies; health
- **Researcher in charge:** José Soares de Andrade Júnior
- **Host institution:** The rector's office of the UFC
- **Municipality/state:** Fortaleza/Ceará

[22] Find out more: https://bv.fapesp.br/en/auxilios/110077/artificial-intelligence-innovation-center-for-health-ciia-health/

[23] Find out more: https://bv.fapesp.br/en/auxilios/109947/cereia-reference-center-on-artificial-intelligence/

According to Professor José Soares de Andrade Júnior, CEREIA aims to become the main center in the state of Ceará and the region for AI and Data Science (AI/DS) initiatives. The project starts with a special focus on health applications that align with specific market demands and state government policies; however, it also takes into account other AI/DS applications under development at the UFC.

During its first five years of operation, CEREIA will focus its research activities on the use of AI applied to solving health challenges. More precisely, the center develops projects in six lines of research: Prediction of chronic diseases; support for evaluation of radiological exams; patient engagement in health promotion and prevention programs; intelligent system for remote monitoring of patients; AI-assisted anamnesis; and high-quality interface for health data science. It is worth mentioning that these research fronts were defined in partnership with Hapvida & NotreDame Intermédica, the center's partner company.

Box 7 – CDI2[24]

General information

- **Lead researchers:** José Alberto Cuminato (USP), Sergio Ferraz Novaes (AI2), João Paulo Papa (Unesp), and Alexandre Xavier Falcão (Unicamp). The group will work in partnership with the National Service for Industrial Training (SENAI) in São Paulo
- **Host institutions:** ICMC-USP, IC-Unicamp, Department of Computing at Unesp (Bauru) and AI2 at Unesp

Inspired by the work of CEPID CeMEAI and AI2, CDI2 aims to increase the training of human resources in Data Science and Computational Intelligence. The center's mission, in turn, is to promote interaction between academia and industry in order to increase the presence of Data Science in the industries of the state of São Paulo. In this context, Professor José Alberto Cuminato explains that all of CDI2's research lines are related to the use of AI/DS to solve industry problems to increase the content of these disciplines in the lives of companies; to do so, the center has the support of SENAI. The project members believe that with greater internal understanding within companies of the benefits and capabilities of information technologies, resistance to their utilization will decrease.

[24] Find out more: https://agencia.fapesp.br/fapesp-anuncia-a-criacao-de-quatro-centros-de-pesquisa-aplicada-eminteligencia-artificial/44775

Box 8 – CENTER OF EXCELLENCE IN ARTIFICIAL INTELLIGENCE FOR RENEWABLE ENERGIES[25]

General information

- **Researcher in charge:** Alvaro Luiz Gayoso de Azeredo Coutinho
- **Host institution:** Coppe-UFRJ

According to Professor Alvaro Luiz Gayoso de Azeredo Coutinho, the center's mission is to advance and implement AI tools and processes for the energy transition towards renewable energies and sustainability, through: Advancing and integrating technologies to increase the generation, storage, distribution and consumption of energy; collaborating with industry in the design, development and transfer of solutions; and providing education and professional training in response to a constantly changing world. The center's work will be structured around Working Groups (WG). The transversal WG0 employs digital technologies and AI for applications in the vertical working groups in wind, solar, biogas, and hydrogen energy (WG1 to WG4). The application areas have different levels of maturity and different demands for AI solutions. One of the center's challenges is to promote consistent progress across all working groups towards the best use of AI technologies suitable for their purposes, always seeking integration and a wide range of collaborations.

Box 9 – CENTER OF EXCELLENCE IN ARTIFICIAL INTELLIGENCE FOR CYBERSECURITY[26]

General information

- **Researcher in charge:** Teresa Bernarda Ludermir
- **Host institution:** CIn-UFPE

The main objective of the center is to research, propose, and monitor cybersecurity solutions involving AI techniques, in three lines of research: Attack and defense, adversarial learning, and cyber-physical applications (CIn, 2023a).

[25] Find out more: https://agencia.fapesp.br/fapesp-anuncia-a-criacao-de-quatro-centros-de-pesquisa-aplicada-eminteligencia-artificial/44775

[26] Find out more: https://agencia.fapesp.br/fapesp-anuncia-a-criacao-de-quatro-centros-de-pesquisa-aplicada-eminteligencia-artificial/44775

Box 10 – PRAIA EDUCATION[27]

General information

- **Researcher in charge:** Geber Lisboa Ramalho
- **Host institution:** CIn-UFPE

With the support of SENAI Nacional, the center's main objective is to "build AI-based solutions that help promote quality, inclusive and up-to-date education, as well as strengthen competency-oriented learning and new education models" (CIn, 2023b).

Conclusion

The creation of CPE/CPA in AI holds a central place in the current formulation of EBIA (Section 1 of this article). For this reason, it is strategic to understand which obstacles must be overcome in order to improve both the process of creating new centers and the operation of existing ones.

One of the difficulties mentioned by the interviewees is the volume of resources for scholarships and computational experiments, which does not match the investments required for the development and dissemination of AI systems. In this sense, one of the researchers consulted pointed out that:

> [...] the low attractiveness of the scholarships in relation to the Information and Communication Technology (ICT) market has limited our ability to gather suitable talent for the project. Furthermore, the inability to hire researchers in modalities that do not involve scholarships or research grants further hindered the assembling of the team, as it restricted our recruitment options.

The observation points to two other obstacles: Operationalizing the CPE/CPA and obtaining additional funding sources. Regarding the first issue, one of the interviewees said that the rules and procedures of the Fapesp program — especially the contact flow for inquires — can slow down the creation of AI centers. As for additional sources of funding, given the attractiveness of jobs in the ICT area outside the academic world, the resources made available by Fapesp-MCTI-MC-CGI.br would need to be supplemented with funding from other organizations. According to the interviewees, although the calls for proposals allow for such supplementation, it would be difficult to execute it. Some of them attribute this difficulty, at least in part, to companies' lack of knowledge on integrating AI into their business activities.

[27] Find out more: https://agencia.fapesp.br/fapesp-anuncia-a-criacao-de-quatro-centros-de-pesquisa-aplicada-eminteligencia-artificial/44775

(...) given the attractiveness of jobs in the ICT area outside the academic world, the resources made available by Fapesp-MCTI-MC-CGI.br would need to be supplemented with funding from other organizations.

Once this obstacle is overcome, another arises: Building solid and fluid alignments among the various institutions comprising the CPE/CPA in AI. As one of the interviewees observes:

> [...] the nature of the research work of a Centre like this needs to maintain the autonomy and decentralization of the operation, while at the same time following common principles and guidelines and allowing centralized visibility of information on results and the progress of projects.

In addition to this internal challenge, the interviewee adds two external ones The lack of regulatory framework for the use of AI in Brazil and the revision of EBIA, which may alter the current guidelines.

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Interview I

Photo: IEA-USP

Fabio Gagliardi Cozman
Full professor at the University of São Paulo (USP).

The academic production on Artificial Intelligence in Brazil

In this interview, Fabio Gagliardi Cozman, full professor at the University of São Paulo (USP), discusses the Brazilian academic production on Artificial Intelligence (AI), presents the advances made by the Center for Artificial Intelligence (C4AI), and evaluates the relevant aspects to Brazilian research into Large Language Models (LLM).

Internet Sectoral Overview (I.S.O.)_ In an interview for Jornal da USP in November 2023, you stated that "Brazil is not completely lost or delayed regarding the uses and applications of AI." In your assessment, what are the highlights of Brazilian academic production on AI? Are there economic sectors and specific areas of AI that should receive greater attention from the Brazilian scientific community?

Fabio Gagliardi Cozman (F.G.C.)_ Brazil has a considerable academic tradition in AI. For years, the country has been around the twelfth position as the largest producer of publications in this area worldwide. This position has dropped slightly in recent years, probably because the pace of investment in AI has grown significantly in several other countries. However, we have a strong academic substrate that can climb many positions if investments are made appropriately. Additionally, Brazil has a set of institutions that produce quality data, such as the Brazilian Institute of Geography and Statistics (IBGE), Oswaldo Cruz Foundation (Fiocruz), National Institute for Space Research (INPE), and the Brazilian Network Information Center (NIC.br); there are also national systems that generate important data, such as the Unified Health System (SUS), and unique records, such as the Individual Taxpayer Registry (CPF). The country has regulations on data usage, already providing an important foundation for AI applications that benefit the population, which is quite positive regarding new technologies in general. Moreover, Brazil has institutions promoting innovation, such as the Financing Agency for Studies and Projects (FINEP), the Brazilian Company of Research and Industrial Innovation (EMBRAPII), Brazilian Micro and Small Business Support Service (SEBRAE), as well as a network of fundraising organizations and startups that, although geographically concentrated, explore many applied aspects of AI.

Some areas have emerged as a focus of interest for new companies: Financial services, agribusiness, health, and human resources. There is also plenty of room in the area of education, both for young people and adults who need to be trained or retrained. At the same time, large companies are

also paying attention to new technologies, and the number of companies that have set up AI study groups in recent years is remarkable. We need to better organize all these vectors, both public and private, and add well-targeted investments. It is also necessary to try to legislate in a measured way, identifying localized problems and regulating through sectoral rules when possible, rather than building general and restrictive laws that can curb innovation.

I.S.O._ Since the C4AI was established, in 2020, what have been its main advances and challenges so far? What results does the center intend to achieve in the next five years?

(F.G.C.)_ The mission of the C4AI is basic and applied research in AI in Brazil, not only producing new results but also discussing and transferring that knowledge to society. The center currently has over ninety researchers with interests in various aspects of AI and invests most of its resources in a set of research challenges that encompass an important subset of the work done by these researchers.

Firstly, the research challenge that has received the most resources in recent years has been the development of tools for processing the Portuguese language, both written and spoken. Another conceptually important challenge is the development of techniques for preserving Brazil's Indigenous languages. An additional set of research challenges focuses on AI applications that process large amounts of data in health (diagnosis and rehabilitation), agribusiness (particularly focusing on food security), and prediction of climatic and oceanic variables. Another important challenge is the construction of conversational agents with the ability to reason and argue. Finally, the center maintains a challenge focused on collecting data and analyzing public policies for AI, thus investigating the impacts of this technology on society. The work has already generated some of the largest sets of linguistically annotated data for the Portuguese language; algorithms for predicting oceanic behavior in ports, decision-making algorithms for food distribution, and indices for assessing national production in AI for Latin America.

In addition, the C4AI has held a series of national and international seminars, as well as round tables, which serve to debate and disseminate the field of AI. Finally, the C4AI has sought to build partnerships with national companies and other institutions — for example, associations of magistrates — and international ones — for instance, the International Research Centre on Artificial Intelligence (IRCAI) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), based in Slovenia. Building partnerships with companies requires willingness on both sides: The university needs to have agility and flexibility in its processes, and the company needs to understand the need for maturity required by good research. This speed adjustment requires constant dialog. But in general, the university has improved its processes and, when contracts follow pre-established standards, the processing is expedited. In this sense, all these aspects of the C4AI should continue to receive attention in the coming years.

"The mission of the C4AI is basic and applied research in AI in Brazil, not only producing new results but also discussing and transferring that knowledge to society. The center currently has over ninety researchers (...)."

"(...) Brazil needs to invest seriously in building models for Brazilian languages (...)."

I.S.O._ Given that most language models are developed outside of Brazil, what contributions could the national academic community make to reduce known issues of this technology, such as "hallucinations," and to adapt them to the Brazilian reality?

(F.G.C.)_ The Large Language Models (LLM) have seen explosive success in recent years, reaching impressive levels of performance in text and image processing. There are two relevant aspects for Brazilian research in LLM. The first aspect is the development of techniques to address current problems found in all LLM. An obvious issue with these models is the generation of false statements, the so-called hallucinations. Another problem is the lack of reasoning: Recent research clearly documents these models' inability to solve logical questions with some complexity. These difficulties, found in all current LLM, do not have an easy solution due to the structure of these models, which is entirely based on emitting the most probable words (or fragments of words) given the previously emitted word sets. There is no reasoning structure in this word generation process. Progress has been made by combining LLM with more traditional computing algorithms, as well as with information verification methods. Several Brazilian researchers are currently working on these topics and should continue to contribute to the academic literature and the creation of new products.

A second important aspect for researchers in Brazil, closely tied to the Brazilian reality, is the development of LLM for Brazilian languages, whether Portuguese (particularly the varieties written and spoken in Brazil) or Indigenous languages. We cannot expect other countries to undertake this development for us because we have a true issue of sovereignty here: Whoever controls the processes of text generation, document creation, and literature of a society effectively controls its culture. Therefore, Brazil needs to invest seriously in building models for Brazilian languages, which involves acquiring large computers capable of processing millions of documents and supporting groups that face the inherent challenges in constructing these models.

Interview II

Brazilian Artificial Intelligence Observatory

Photo: Personal archive

Luiz Alexandre Reali Costa
Manager of the Brazilian AI Observatory (OBIA).

In this interview, Luiz Alexandre Reali Costa, manager of the Brazilian Artificial Intelligence Observatory (OBIA), discusses the creation, objectives, and operation of OBIA, as well as its relationship with the national and international ecosystems of Artificial Intelligence (AI).

Internet Sectoral Overview (I.S.O.)_ What motivated the creation of OBIA? What are its objectives and how does it work?

Luiz Alexandre Reali Costa (L.A.R.C.)_ The OBIA operates as a focal point in Brazil for monitoring and analyzing the evolution and impact of AI and collaborates with multisectoral partners, both domestic and international.

The OBIA is the result of a strategic action within the context of the Brazilian Artificial Intelligence Strategy (Estratégia Brasileira de Inteligência Artificial [EBIA]), established through an ordinance of the Ministry of Science, Technology and Innovation (MCTI) (MCTI Ordinance No. 4.617, of April 6, 2021, amended by MCTI Ordinance No. 4.979, of July 13, 2021).[28] OBIA emerges as a response to the need for monitoring and analyzing the advancements and impacts of AI in Brazil. Currently, EBIA is under review by the MCTI.

The establishment of OBIA was motivated by the growing importance of AI across various sectors and the need for a coordinated approach to understand and guide its development in the country. Its main objectives include collecting and analyzing data on the adoption and use of AI, promoting a multidisciplinary vision to encompass the various facets of AI, and fostering cooperation among multiple stakeholders, including government, academia, the private sector, and civil society.

EBIA, in turn, aims to guide the actions of the Brazilian state, promoting research, innovation, and the development of AI and its enabling technologies. Inspired by the principles of responsible and ethical AI defined by the Organization for Economic Cooperation and Development (OECD), EBIA stipulates nine thematic axes. These include: Education; workforce and training; research, development, and innovation (RD&I) and entrepreneurship; application in productive sectors; application in public authorities; public security; legislation, regulation, and ethical use; AI governance; and international aspects.

[28] Find out more: https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/transformacaodigital/inteligencia-artificial#:~:text=Institu%C3%ADda%20pela%20Portaria%20MCTI%20n%C2%BA,v%C3%A1rias%20vertentes%2C%20que%20estimullem%20a

"The creation of OBIA was a complex process that brought challenges in keeping up with the speed and scope of AI advancements and required the integration of multiple perspectives and methodological and coordination improvements among the data-producing partners that feed the observatory."

In the cross-cutting axis of AI governance, EBIA proposes the creation of OBIA, an AI observatory in Brazil that can connect with other international observatories.

The Brazilian Internet Steering Committee (CGI.br) and the Brazilian Network Information Center (NIC.br), especially through its Regional Center for Studies on the Development of the Information Society (Cetic.br), play a crucial role in coordinating this axis, due to their experience in monitoring the adoption and advancements of information and communication technologies (ICT) in Brazil.

OBIA operates with a focus on three fundamental pillars. The first one is multidisciplinarity, which acknowledges that AI has been developed in all sectors and promotes a multidisciplinary approach engaging experts from different fields, such as science and technology, innovation, education, health, training, and public safety. The second pillar is based on data and evidence. OBIA provides relevant data and information as evidence, serving as a basis for decision-making, the development of appropriate public policies, as well as AI research and development. The third pillar is multi-stakeholder cooperation, in other words, fostering cooperation and participation of multi-stakeholders, such as the government, academia, the private sector, civil society, and international organizations.

I.S.O._ During the creation of OBIA, what were the main references adopted and the main obstacles encountered? How were these obstacles overcome?

L.A.R.C._ The creation of OBIA was a complex process that brought challenges in keeping up with the speed and scope of AI advancements and required the integration of multiple perspectives and methodological and coordination improvements among the data-producing partners that feed the observatory. It required establishing strategic partnerships, conducting development workshops, and actively participating alongside international institutions and forums.

During the creation of the observatory, the main references and obstacles faced were related to defining strategies for the effective monitoring of AI in Brazil.

The first adopted parameter was the definition of what and how to monitor the development of AI in Brazil, establishing clear indicators for monitoring, both quantitative and qualitative metrics, along with recommendations, risk assessments, strategic documents, and regulatory proposals. Secondly, strategic partnerships, and collaborations with institutions such as MCTI, the Center for Strategic Studies and Management (CGEE), the State Data Analysis System Foundation (SEADE), the Center for Artificial Intelligence (C4AI), and Cetic.br|NIC.br, were fundamental, as these entities brought valuable knowledge and resources necessary for the success of the project. Lastly, international integration, meaning participation in global forums and cooperation with organizations such as the International Telecommunications Union (ITU), the

United Nations Educational, Scientific and Cultural Organization (UNESCO), and the OECD, were crucial in aligning OBIA's efforts with international practices. The OECD, in particular, provided a reference model on AI on its portal.[29]
Regarding the obstacles, the first challenge was the diversity of sectors involved. Governments, legislators, scholars, industry, and the general population have different interests in AI. Overcoming this obstacle came by adopting a multisectoral approach, promoting inclusive dialogues and workshops to produce statistical data, initially, with the aforementioned institutions and continuing to expand, partnerships with other institutions, new AI centers, and scholars with related projects.
The second obstacle concerns methodology and data visualization. The need for research, analysis, and data visualization methods that keep pace with the speed and complexity of AI development was a significant challenge, which was overcome by the adoption of innovative technologies and practices, such as Big Data, web scraping, and strategic partnerships for data collection and analysis.
Finally, the third challenge was international coordination. Given the rapid development of AI and the associated risks, it was necessary to establish effective coordination with international institutions. This has been achieved through active participation in international working groups, that define principles and map risks, as well as propose recommendations for the development of a reliable and ethical AI.

I.S.O._ What are OBIA's work agendas in the short and medium term? The national and international AI ecosystems comprise numerous stakeholders. How has OBIA sought to engage with them?

L.A.R.C._ OBIA is on a path of continuous development and improvement. The year 2023 was a structuring year for laying the foundations for operations, obtaining initial data and indicators, establishing strategic partnerships, and building international relationships.
As we enter 2024, OBIA has focused on presenting the results achieved so far and expanding its partnerships, which will allow for the inclusion of new indicators. Increasingly essential and relevant topics — such as the impact of AI on the job market, ethics, and data protection — highlight the growing need for a careful and well-thought-out regulatory approach.
This issue represents a complex challenge: Balancing regulation without hindering the innovative development of AI. Excessive regulations can inhibit innovation by imposing bureaucratic and legal burdens on developing companies, where the risk of breaking the rules may be high.
Although AI-related topics are widely present in the news and media in general, there is a gap in public understanding and clarification of the risks and consequences associated with this technology.

"OBIA is on a path of continuous development and improvement. (...) As we enter 2024, OBIA has focused on presenting the results achieved so far and expanding its partnerships, which will allow for the inclusion of new indicators."

AI emerges at a time accompanied by expectations, on the one hand, to

[29] Find out more: https://oecd.ai

"(...) OBIA is actively strengthening its relationships with both global entities and local partners, asserting its presence in forums and working groups of considerable importance."

solve social problems, for example, by improving access to health and education, including social layers that currently have no access to these services; and, on the other hand, to accentuate differences, even widening disparities between nations, especially between developed countries and those in the Global South.

At present, Brazil has assumed the temporary presidency of the G20; in this context, the Digital Economy Working Group (DEWG) of the G20 has defined AI as one of its four priority themes. This prioritized working group will delve deeper into the theme of AI for sustainable development and inequality reduction (*Artificial Intelligence for Sustainable Development and Inequalities Reduction*).

Thus, in summary, OBIA intends to launch a portal with indicators and data repositories, encompassing both quantitative data and qualitative documents, publicly accessible, expanding partnerships and incorporating new indicators from other centers and researchers, as well as disseminating AI-related risk issues such as data protection, ethical use and implementation of AI, security, topics like explainability, transparency, biases, among others, by OBIA's portal and by promoting and participating in debates and workshops.

Finally, OBIA is actively strengthening its relationships with both global entities and local partners, asserting its presence in forums and working groups of considerable importance. The year 2023 was characterized by a concentrated effort to establish a solid foundation and form strategic alliances. Now, in 2024, OBIA's focus shifts to disseminating the results achieved and making final preparations for the launch of an innovative data visualization portal, which promises to be a valuable tool for promoting transparency and access to information in the field of AI.

Article II

Recommendations for the advancement of Artificial Intelligence in Brazil[30]

By the Brazilian Academy of Sciences[31]

Introduction

Until recently, Artificial Intelligence (AI) sounded futuristic and distant, but this reality changed dramatically a few months ago. The development of tools such as ChatGPT — and so many others that are emerging, quickly and affordably — has brought AI into the public debate and, more than that, into our daily lives. AI is a powerful set of technologies for diverse uses, offering opportunities to boost Brazil's economic and social growth. In the research and innovation ecosystem, it is an essential element in fostering discoveries in all areas of science, reaching all sectors of the economy and society.

Taking advantage of AI's range of opportunities requires a good understanding and management of the benefits and risks associated with it. This is why it is necessary to invest effectively in research, development, and innovation (RD&I) and training human resources. These investments should pave the way for solutions to Brazil's challenges, promote responsible innovation, contribute to the public good, protect people's rights and security, and advance democratic values.

In this report, the Brazilian Academy of Sciences (ABC) presents a brief analysis of AI at a global level and makes recommendations for the advancement of AI in Brazil. The document is the result of the efforts of a working group made up of researchers from various fields of knowledge. The group sought to chart a path and indicate strategies for the growth of AI in the country. The development and use of reliable AI systems, including data and infrastructure, also aim to prepare the current and future workforce for the successful application of AI in the various sectors of society, leveraging economic development.

[30] Edited version of the homonymous work published by the Working Group on Artificial Intelligence (GT-IA) of the Brazilian Academy of Sciences (ABC) in November 2023. The original version is available at: https://www.abc.org.br/wp-content/uploads/2023/11/recomendacoes-para-o-avanco-da-inteligencia-artificial-no-brasil-abc-novembro-2023-GT-IA.pdf

[31] The GT-IA is coordinated by Virgílio Augusto Fernandes Almeida. The document was drafted by a group of 16 researchers: Adalberto Fazzio; Altigran Soares da Silva; Anderson da Silva Soares; André Carlos Ponce de Leon Ferreira de Carvalho; Edmundo Albuquerque de Souza e Silva; Elisa Maria da Conceição Pereira Reis; Fabio Gagliardi Cozman; Helder Takashi Imoto Nakaya; José Roberto Boisson de Marca; Luís da Cunha Lamb; Mario Veiga Ferraz Pereira; Nivio Ziviani; Soraia Raupp Musse; Teresa Bernarda Ludermir; Virgílio Augusto Fernandes Almeida; Wagner Meira Júnior.

The influence of AI extends across many sectors (...). In developed countries, universities have created multidisciplinary AI centers to drive advances in drug development, genomic data analysis, and innovative technology projects to improve the quality of life in cities.

The following pages are divided into four sections. The first one provides a macro-analysis of the workforce required to advance the development of AI in Brazil. The second one describes the potential use and application of AI in critical areas of the economy, society, and government, highlighting the opportunities for increased competitiveness and innovation in areas such as health, education, the environment, and energy. Next, a reflection is proposed on the risks of AI for society, individuals, and organizations. Finally, the fourth section presents recommendations for Brazil to advance in the responsible use of AI.

The technological gap between AI in Brazil and the international stage – diagnosis of challenges and opportunities

The technological advances resulting from the Industrial Revolution and 19th-century agriculture led to the end of labor-intensive farming and consequently caused major changes in professions and the labor market. At the time, disruptive innovations (such as the combustion engine, electricity, and the chemical industry) quickly created a range of job opportunities, absorbing the displaced workforce. These innovations have stimulated investment, generated wealth, trained a new class of workers, and brought social benefits. In recent years, this reality has changed: The industrial sector has lost investment and competitiveness, putting innovation in the Brazilian economy in a particularly worrying situation (Brazilian Institute of Geography and Statistics [IBGE], 2022).

The current revolution, however, is much more far-reaching. Driven largely by computing, data communication, and now AI, this movement has led to the concentration of power by a relatively small group of countries, organizations, and people. This is due to the highly specialized nature of well-paid jobs, concentrated on highly educated professionals who master these new technologies. At the same time, the people displaced by this new demand for professionals are relegated to lower-skilled and lower-paid jobs and could eventually be replaced by AI-based systems and robots.

The influence of AI extends across many sectors, including agriculture, biotechnology, education, engineering, humanities, the environment, health, and entertainment. In developed countries, universities have created multidisciplinary AI centers to drive advances in drug development, genomic data analysis, and innovative technology projects to improve the quality of life in cities.

The opportunities associated with these advances predominantly concern those with higher levels of education. In this sense, the prospects are not promising even for those at intermediate levels in the socioeducational hierarchy. To cite a few examples, jobs that used to pay well, particularly in developing countries, such as computer programming, are about to be supplanted by advances in AI. There is a tangible risk that, in the near future, only highly qualified programmers will continue to be employed. This risk also threatens areas such as education, law, health, and administration.

Brazil cannot be at risk of just being a user of AI solutions designed abroad. Dependence on other countries and large companies in this area can harm national security and sovereignty, as well as the competitiveness of national companies at home and abroad. Countries that want to build new technologies based on AI must be able to understand the principles of developing these solutions. Otherwise, the lack of knowledge will perpetuate an ever-increasing dependence on large corporations and technology-dominant countries.

As in other developing countries, the Brazilian context is critical: It is known that only a small portion of our population has access to quality education. Although the country has world-renowned scientists in various fields — including AI — it lacks the critical mass needed to drive significant technological advances, or even to make proper use of technology (which is rapidly and constantly changing) on a scale that favors sustainable technological growth. The situation becomes even more worrying with the recent advances and proliferation of so-called Large Language Models (LLM) (Ahmad et al., 2023).

Brazil still lacks comprehensive mastery of this essential technology to analyze the results of the models and their implications, as well as to effectively critique the applications developed using this technology.

It is clear that, based on innovation, the number of articles published and cited, the number of patents filed, and the volume of investments,[32] the leading nations in AI are the United States, China, France, Germany, Russia, India, Switzerland, Japan, Korea, the Netherlands, Sweden, Finland, Ireland, Singapore, Canada, Israel and Italy. Brazil appears among the top twenty countries in some rankings, mainly due to the significant number of publications (approximately 10% of the number of articles published by the USA). However, when analyzing the urban centers with the greatest development in AI (the so-called AI hotspots), only São Paulo stands out in Brazil, and, although it appears in the ranking of the top 50 cities with AI talent, it is in 44th place (four positions below Buenos Aires). San Francisco, for example, ranks first in several ordinations. In short, the US is home to approximately 60% of the leading AI researchers. Next on the list are China (11%), Europe (10%), and Canada (6%). This distribution is not surprising, given the concentration of universities with the highest international reputation, large AI technology companies, and the number of startups in and around the AI hotspots.

It should also be noted that the number of graduates in computer science and computer engineering in the US has grown steadily, from 10,000 in 2010 to more than 33,000 in 2021, while the number of Ph.D. graduates graduating per year has remained stable (around 1,800 over the last 11 years) (Standford University Human-Centered Artificial Intelligence, 2023). On the other hand, the fraction of Ph.D. holders specializing in AI grew from approximately 10% to 19% in the same period (Maslej et al., 2023). In Brazil, according to the 2019 Coordination for the Improvement of Higher Education Personnel (Capes) area document, the number of doctors graduating annually in computing was below 400 in 2016 and is not expected to have increased during the COVID-19 pandemic.

Brazil cannot be at risk of just being a user of AI solutions designed abroad. Dependence on other countries and large companies in this area can harm national security and sovereignty, as well as the competitiveness of national companies at home and abroad.

[32] For more information, see: MacroPolo (2023); Chakravorti (2022); Chakravorti et al. (2021); SCImago Journal & Country Rank (s.d.); China Daily (2023); Savage (2020); and The São Paulo Research Foundation (FAPESP) (2020).

For the development of AI in Brazil, it is essential to encourage the training of students with qualifications at the same level as the leading foreign institutions. Researchers in the field must be able to contribute to scientific and technological progress (...).

For the development of AI in Brazil, it is essential to encourage the training of students with qualifications at the same level as the leading foreign institutions. Researchers in the field must be able to contribute to scientific and technological progress, propose innovative solutions in the field, and critically analyze solutions proposed by corporations. In addition to the low growth in the number of professionals with the necessary training, a growing number of these professionals are choosing to work abroad. A crucial challenge for Brazil is to create the infrastructure, qualifications, and human resources to keep up with and take a leading role in the evolution of AI technologies.

The outlook for patents is not encouraging either. According to a recent study (Machado & Winter, 2023), the vast majority of patents filed in Brazil related to AI stem from technologies developed in the US, despite the reasonable number of publications on AI by Brazilian researchers.

Students from leading Brazilian universities have been attracted to AI areas, but the number of qualified professionals in relation to the national population remains quite low (Google for Startups, n.d.). In addition, as already mentioned, the appeal of job markets with more attractive positions and salaries in other countries has led to a notable brain drain of students and professors, which negatively impacts Brazil's ability to create an environment conducive to innovation and the development of startups in AI and related areas. It is also important to note that professionals hired by large foreign and multinational high-tech companies receive much higher salaries than the amounts paid via national research grants. This highlights the challenge that startups and small and medium-sized national companies face in competing for talent. Furthermore, current market demand requires students to devote more time to advanced studies. The combination of grants and low salaries, with unsatisfactory working conditions within academia, has discouraged talented students from pursuing academic careers, creating a vicious cycle of decline in the education of future generations of scientists.

AI has been the subject of academic research for decades, mainly on three fronts. First, there are lines of research that seek to understand the mechanisms of intelligent behavior and support studies in areas such as linguistics, logic, philosophy, psychology, sociology, and neurophysiology. The second front goes in the opposite direction, using knowledge from these areas to propose algorithms capable of replicating "intelligent behavior" in machines. One example is the design of new machine learning algorithms. Here, a parallel can be drawn with the study of nuclear energy, whose scientific exploitation over time has led to unexpected advances, such as in nuclear medicine. The third front is more related to the search for short and medium-range technology and innovation, investigating where and how AI can be used in a wide variety of applications to solve real problems or help advance other areas of knowledge. The aim is to reduce risks, reduce manual and repetitive work, improve environmental and social conditions, and increase efficiency. The recent achievement of various scientific and technological advances and innovations, albeit still partial and incomplete, has made the practical impact that AI can have on society and the planet more tangible. At the same time, this success has heightened the perception of the risks that this technology brings with it.

In short, this diagnosis draws attention to the Brazilian context on the international stage. Without adequate investment and lasting and appropriate public policies, the global AI framework could push Brazil into an unprecedented technological decline. The gap between the countries at the forefront of AI RD&I and the rest is growing at exponential rates. It is imperative that Brazil establishes public policies and investments to reverse this trend without delay. If inertia persists, the negative impact will be felt in the short term in education, other social indices, and the economy, with a consequent lack of business competitiveness in all areas.

Potential use and applications

The impact of the appearance of AI in the 21st century is similar to that of the appearance of the Internet in the 20th century. The advance of AI, however, has occurred at a much faster pace. This has encouraged governments such as China, the United States, European Union countries, and the United Kingdom to implement strategic AI investment programs with large and immediate financial contributions. In this context, countries and corporations that lead the way in the development and effective use of this technology will increase their competitiveness on the world stage (Solaiman, 2023).

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As already mentioned, Brazil's situation in this scenario is particularly worrying, given that its industrial park has lost investment and competitiveness in recent years. The federal government has promised a reindustrialization effort, but this will require policies that put the Brazilian industry in a competitive position — which depends on mastering digital technologies and, in particular, AI.

Many sectors of the economy should benefit from the intensive use of AI. In the United States, for instance, AI is being deployed by companies in various applications. According to the *Artificial Intelligence Index Report 2023* (Maslej, 2023), the AI capabilities that have seen the greatest adoption in companies include: Robotic process automation (39%), computer vision (34%), natural language text understanding (33%) and virtual agents (33%). It should also be noted that in 2022, the most prevalent AI use case was the optimization of service operations (24%), followed by the development of new AI-based products (20%), customer segmentation (19%), customer service analysis (19%) and AI-based improvements to existing products (19%).

In Brazil, there are strategic areas that could strongly benefit from the use of AI. Below are some sectors that could make significant contributions to the growth of the economy, as well as to improving the quality of life of the Brazilian population, including the scope and quality of public services.

HEALTH

AI has the potential to significantly impact the health sector and the wider sphere of public policy related to the issue. Its ability to analyze large volumes of data, anticipate trends, and make predictions can help in the identification of diseases, patient care, and the efficient distribution of resources, which can save lives and minimize costs. There are many practical examples of the use

AI can also be applied to diagnosing and identifying diseases, personalizing treatments, discovering, and developing medicines, and supporting administrative tasks.

of AI in the public sector, ranging from identifying fraudulent benefit claims to tracking the spread of disease. AI can also be applied to diagnosing and identifying diseases, personalizing treatments, discovering, and developing medicines, and supporting administrative tasks.

Combined with the development of low-cost sensors, advances in machine learning have the potential to significantly improve healthcare, especially by complementing existing clinical decision support systems. These technological advances can empower doctors, home caregivers, and other health professionals, optimizing the delivery of care. This is especially important considering the growth of the elderly population in Brazil, with an increasingly high demand for healthcare facilities both at home and in clinical settings.

Telehealth is an example of where AI can be effective by extending the supply of medical services to rural and/or hard-to-reach regions. In this sense, this technology could have an impact on the treatment of Chagas disease — a neglected pathology that is endemic in continental America and more frequent among poor people who live or have lived in the countryside. Recognizing cases early allows for anti-parasitic treatment when there is no heart disease, or, when there is heart disease, to treat it in good time. An AI algorithm based on a neural network has already been developed to identify chagasic patients by ECG (Jidling et al., 2023).

AI can also help improve the quality of care, increase accessibility, save resources, combat the shortage of health professionals, and improve disease surveillance and public health as a whole. This technology can be used to develop systems that help decision-makers navigate complex choices, providing insights and recommendations based on data analysis. This can be particularly useful for policymakers and health managers. In healthcare, the use of AI in developed countries is already significant and growing, allowing professionals to act with more precision, focus, and assertiveness. The expectation is that AI solutions will be able to help individuals and patients with self-care, doctors and health professionals with the diagnosis and treatment of diseases, and health managers with the programming of preventive actions and the organization of health care, optimizing the use of resources and improving the health of people and populations.

ENERGY

Basically, in the energy sector, there are three main areas of AI application: (a) description, the use of AI to model physical phenomena (such as rainfall and temperature), equipment (such as a turbine-generator set), and quantities of interest (such as energy demand); (b) prediction, the use of AI integrating descriptive models with probabilistic processes to produce future scenarios, such as the probability of rainfall, the demand variation, or “yellow lights” in the behavior of the turbine-generator set; and (c) decision-making, the use of optimization techniques under uncertainty (such as deep reinforcement learning) to support the decision-making, for example, in reservoir operation or predective maintenance.

Still considering these areas of application, AI makes it possible to better represent phenomena that are difficult to capture by traditional probabilistic models, such as the temporal and spatial variability of renewable production and demand over shorter intervals — topics that have gained relevance with the strong inclusion of wind sources and distributed generation (DG), among others. There are also benefits in the intelligent use of existing resources. Predictive maintenance is one example: It can be more effective and cheaper than traditional periodic maintenance. Two challenges that must be considered in the energy sector are the proper curation of the data used to train algorithms and the possibility of some unexpected and severe AI failure, which can occur due to the difficulty of understanding the paths followed by machine learning algorithms.

Brazil is in a privileged position to make the energy transition, an essential process for tackling climate change. In this context, AI can help optimize and integrate various energy sources, such as hydroelectric, wind, and solar, gradually reducing dependence on fossil generators. The transition from a centralized grid to decentralized grids requires the creation and development of innovative technologies capable of optimizing solutions that contain a combination of information from different energy sources. These innovative technologies will require the use of modern machine learning techniques.

Finally, AI will be fundamental to the process of decentralizing low-voltage energy production, which will give consumers the possibility of producing energy through DG and modulation and flexibility services with the support of batteries. Digitalization (smart meters, communication, etc.) is fundamental to this process. In the case of decarbonization, the main benefits of AI should come from new atmospheric circulation models, the ability to analyze massive amounts of satellite information for rain and temperature forecasting, and the aforementioned ability to better represent the production of renewable sources.

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FINANCIAL

The financial sector collects and stores a large volume of data. Banking, financial and insurance institutions can benefit greatly from AI resources. One of the areas that could see great progress is security: Financial institutions are currently fighting a constant battle with hackers and fraudsters. Through AI, patterns can be used to identify fraud before it affects customers and institutions. Other benefits include customer relations, process automation, and forecasting possible difficult situations for customers, including defaults. In addition, financial institutions' databases — which reflect the spending and investment patterns of the Brazilian population — can, with the use of AI, contribute to the analysis of public policies with positive impacts on reducing social inequality.

BIODIVERSITY, BIOTECHNOLOGY, AND CLIMATE CHANGE

As is well known, Brazil has a rich and diverse fauna and flora, which generates immense potential in the field of biodiversity and biotechnology. There are important biodiversity databases in the country, such as one dedicated to Brazilian flora with the aim of promoting applications in the pharmaceutical

AI can help understand and predict the impacts of climate change (including disasters of all kinds), support food and water security actions, and even characterize and protect biodiversity, among many other application scenarios.

sector.[33] Recovering and centralizing this information to be used by AI models is a crucial step toward harnessing the enormous potential that this area represents for Brazil.

With the acceleration of deforestation in our territory, monitoring changes in ecosystems is extremely important. Tracking animals in our flora, for example, is done by using techniques called camera traps. However, recent studies suggest that air sensors could revolutionize animal tracking by analyzing environmental DNA (eDNA) captured by air quality monitoring stations in the environment (Jidling et al., 2023). The resulting eDNA data can be used to make predictions about species, and advances in AI can improve species distribution models. An example of the use of this technology is the AquaGen project,[34] funded by the European Union. The initiative combines environmental genomics and machine learning to predict the quality status of aquatic ecosystems based on DNA detection of bioindicator species (Gilbert, 2023).

So-called discriminative AI can be used to decipher the language of genomes and thus predict new viral variants, as demonstrated by recent research conducted by researchers at the California Institute of Technology (Caltech-USA) (Ahmad et al., 2023). This same technology can be used for weather and climate change forecasting, which is made feasible by the significant acceleration of simulations that the method provides. Climate risk assessments can thus be improved, with the potential to save lives and positively impact agriculture, a sector susceptible to climate change and extreme weather events.

In the context of environmental studies, it is important to highlight the volume of data and the complexity of existing descriptive and predictive models. AI can help understand and predict the impacts of climate change (including disasters of all kinds), support food and water security actions, and even characterize and protect biodiversity, among many other application scenarios.

EDUCATION

Education is one of the areas in which LLM can have a significant impact in Brazil. As highlighted in a recent report by the United Nations Educational, Scientific and Cultural Organization (UNESCO), AI has the potential to tackle some of the biggest challenges in education (UNESCO, 2021). The document points out that personalized learning systems are being perfected by the private sector for implementation in schools and universities around the world. However, in the context of Brazil, it is imperative that the public sector plays a proactive role in tackling educational challenges.

Data is the basis of AI applications, and it is therefore essential that it is accurate, unbiased, and well-curated. The models that support AI applications in education must be transparent and open to society. Developing expertise in these areas is key. In addition, the data and models must be adapted to meet the specific needs of Brazilian students. They must therefore consider cultural nuances, local languages, and the socioeconomic context in which the education system operates. It is also essential that educators and students are prepared with the necessary knowledge to effectively use the new AI technologies.

[33] Find out more: https://revistapesquisa.fapesp.br/arquivo--natural
[34] Find out more: https://cordis.europa.eu/project/id/886209

AGRICULTURE

Agriculture and food production need to intensify the use of AI, Big Data, and high-performance computing technologies to create opportunities in the multidisciplinary field of agricultural technologies. Examples of sectors that can benefit from intensive data science in agriculture include crop management, animal breeding (including animal welfare and animal production), and water and soil management.

SCIENTIFIC RESEARCH

AI technologies can substantially reduce the time and resources needed to carry out experiments and, at the same time, produce results with greater precision and reliability. The technology will give research teams great capacity to identify new methods of optimizing existing processes and to develop more effective solutions with more innovation. In addition, AI will make it easier to build models that can be used to predict results and thus lead researchers to make more accurate and assertive decisions. In this sense, AI should also have a positive impact on companies, with possibilities for improvements in research and development (R&D), allowing them to bet on more ambitious projects and reduce risks. The field of materials is a current and interesting example of the application of AI in basic research, with enormous benefits expected (Schleder, 2019). The Materials Genome Initiative (MGI),[35] launched in the United States in 2011, seeks to use AI to significantly reduce the time taken to discover new properties and new materials. Data from complex materials is used to make new thermoelectric compounds, new additive manufacturing alloys, and new magnetic materials, as well as facilitating the search for so-called quantum materials, which are expected to have a major impact on the field of electronics with their applications in quantum computers. The results of this research are expected to fuel the world economy for decades to come: From them, products will emerge that will not only bring well-being to the population but also wealth to the nations that embark on this new way of doing science.

AI technologies can substantially reduce the time and resources needed to carry out experiments and, at the same time, produce results with greater precision and reliability.

COMPETITIVENESS OF COMPANIES

Competitiveness is the ability of any organization to fulfill its mission more successfully than its competitors. Bearing in mind that the impact of AI is increasingly clear for companies and society, with major transformations in large areas such as education, energy, health, and sustainability, it is important to understand the more structural dimensions of the use of AI in the business sector.

In the context of the advance of AI in the world, the competitiveness of national companies brings multiple challenges. Defining and implementing a strategy to achieve long-term goals and objectives is one of them. Without adequate strategies, there is no generation of value. In general, companies (as well as public organizations, including educational and research institutions) suffer from a lack of technical understanding of AI, which represents an obstacle to incorporating AI tools into their processes.

[35] Find out more: https://www.mgi.gov/

The use of AI can make a significant contribution to the relationship between government and citizens. (...) Potentially, the technology will bring gains in the integration of sectoral policies at different levels, maximizing collaboration between municipal, state, and national initiatives.

The sustainability of technology is another challenge, which occurs when there is no proper understanding of its use, such as with AI. The search for competitiveness in the country's economy also requires the development of national technologies that create value and competitive Brazilian products on the international market. Thus, the mere acquisition of products and technologies from abroad is not enough.

A relevant point about AI in business competitiveness is the development of consumer-centric solutions. In a real case, a company has created an authorizer for clinical examinations on patients using AI that allows the doctor, during a consultation, to interact with the health insurer. The professional requests a series of tests and, within seconds, has the authorization response. In this way, the customer's workload and waiting time are reduced, lowering the health insurer's costs. It's a sustainable technology that creates value for the company and its customers.

EFFICIENCY AND GOVERNANCE IN THE PUBLIC SECTOR

The use of AI can make a significant contribution to the relationship between government and citizens. On the one hand, the large and dispersed volume of data on public policies could be integrated to maximize their efficiency and effectiveness. Potentially, the technology will bring gains in the integration of sectoral policies at different levels, maximizing collaboration between municipal, state, and national initiatives. On the other hand, the very integration and systematization of the mass of public administration information enables citizen control and ensures more democratic management.

Ethical and social risks

Despite the potential benefits and opportunities, there is concrete evidence that AI technologies can cause harm to individuals, groups, societies, and the planet. Among the concerns are privacy violations, the creation of anti-competitive environments, manipulation of behaviors, and the occurrence of environmental disasters. Machine learning algorithms already enable the identification and exploitation of vulnerabilities and biases — with identified cases of perpetuation, such as racial issues and other forms of discrimination.

AI can directly affect various profiles of workers, either by monitoring their performance or by excessive automation — factors that can lead to worsening working conditions or even the extinction of roles. These risks already existed with the adoption of other technologies, but with AI, the impact could be greater, not limited to easily automatable jobs that require little qualification, but also interfering with positions that require analytical ability, information processing, and some degree of creativity. A report by the McKinsey consultancy, published in 2015 (therefore, before the current impact of AI), already pointed out the consequences of this technology on jobs with medium and high pay, which are also and will be affected by the use of AI in the labor market (Chui et al., 2015).

In response to these and other concerns, a set of initiatives called Responsible AI (Pak, 2022) has emerged. In the project, AI-based applications, models, and systems go beyond typical technical features, aiming at social goals and avoiding harm to individuals and groups (Pak, 2022). It is crucial that, in Brazil, concerns about ethical and social risks guide the establishment of principles, rules, and legislation to minimize technology risks. It is also essential for Brazilian society to participate in discussions about the limits of AI use. Different actors in society have expressed fears related to the tool. For scientists, it is of interest to protect national development on par with international progress, not allowing delays or limitations in scientific and technological progress and providing equality in scientific and technological development and in the generation of innovations and wealth.

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REGULATION TO MINIMIZE RISKS

The main challenge in building regulation for AI is that the rules and laws are fair, inclusive, and protective of society. At the same time, they should not delay or halt the development of technology. It is a sensitive, dynamic challenge that needs to be well-discussed by various sectors of society.

There is another important aspect to consider: New rules and laws should not unnecessarily overlap with existing ones. For example, it is necessary to clarify which elements of data protection and consumer protection are not covered by the respective laws and therefore deserve new regulations. Another challenge is that the legislation to be established must provide assurance to the population about what is and is not prohibited. Due to its rapid evolution, AI technologies do not easily conform to static definitions.

The debate on AI regulation extends worldwide. Here, Senate Bill No. 2338 of 2023 is under consideration. The discussion was initiated within the scope of the Brazilian Digital Transformation Strategy (E-Digital), approved in March 2018 through Decree No. 9319/2018 and by ministerial ordinance MCTIC No. 1556/2018. The Ministry of Science, Technology, Innovation and Communication (MCTIC), through another ministerial ordinance (MCTIC No. 1122/2020), defined AI as a priority in research projects and in the development of technologies and innovations for the period 2020 to 2023 (Bill No. 2338/2023). In this context, the Brazilian Artificial Intelligence Strategy (EBIA) was drawn up. Many concerns have been voiced by different social actors, particularly regarding ethical issues, civil liability, privacy, and security.

Despite these legislative initiatives, Brazil still has no regulations on AI. It should be noted that discussions on international regulations face the same challenges as the country: Reconciling specialized knowledge in AI with legal knowledge in an area of constant and accelerated evolution. In June 2023, the European Union announced that the use of AI will be regulated by its *AI Act* (European Parliament, 2023), with the approval process already underway. The European Parliament's priority is for AI systems used in the European community to be safe, transparent, traceable, non-discriminatory, and sustainable. Therefore, critical AI systems may require human supervision.

To accelerate its growth with the successful use of AI, Brazil will need to have a qualified critical mass of professionals who master areas and subareas related to AI (...). It is also urgent to demystify and inform society about what AI really is.

The *AI Act* (European Parliament, 2023) is fundamentally risk-based, proposing different rules for risks of different dimensions. In particular, there are risks considered unacceptable, including cognitive behavioral manipulation of vulnerable people or groups, biases of various kinds (gender, sex, age, etc.), techniques for providing social scoring, and real-time biometric identification systems. These uses are prohibited by the *AI Act*. High-risk activities, such as use in personnel selection or medical device operations, are permitted, but subject to prior application analysis. Activities with lower risk but with transparency issues—such as the use of software robots for opinion generation—are allowed, but subject to requirements such as notifying users about the nature of the interactions. Finally, activities with minimal or without risk are permitted without restrictions. A relevant aspect of the *AI Act* is the provision of regulatory sandboxes, i.e. reserved spaces that facilitate the development and testing of AI innovations.

The United States also lacks specific regulations or legislation. The US strategy for AI is defined through legislation and orders (acts, decrees) by the executive branch. A set of documents has been produced and revised periodically. Because it is constantly advancing, the mobilization of entrepreneurs, researchers in the sector, and economic, social, and political leaders must be equally continuous. Provisions approved in 2021 stipulate general rules in the context of the technological dispute between the US and other countries, particularly foreseeing the creation of a national network of AI research institutes. Recently, the US government presented the Blueprint for an AI Bill of Rights (White House [United States], n.d.), which defines a set of principles and associated practices that assist in the use and deployment of AI systems and protect the rights of the population in this era of AI. The five basic principles presented in the document are: (a) users should not be subjected to unsafe or ineffective AI systems; (b) they should not suffer algorithmic discrimination; (c) they should not be subject to abusive data collection and should be informed about collected data; (d) they should know when AI systems are used and how they contribute to outcomes; and (e) they should have the power to avoid AI systems and access humans when necessary.

Recommendations

To accelerate its growth with the successful use of AI, Brazil will need to have a qualified critical mass of professionals who master areas and subareas related to AI, such as machine learning and data science. Training this body of professionals takes time. Countries and companies with technological leadership began this training at least ten years ago. Brazil needs to tackle this challenge quickly and on a large scale. It is also urgent to demystify and inform society about what AI really is. In this sense, the child population deserves special attention. In some countries, simple AI concepts, clear indications of how it works, and where it has been used are topics that are already addressed in elementary school. Brazil teaches little or nothing about simple concepts of computational thinking in its schools.

HUMAN RESOURCES TRAINING

Some strategies can help retain talents from the country's educational ecosystem and foster a well-equipped and locally cultivated workforce. Human resources training should promote research and development with public and private investment; promote the union of university researchers with company researchers to stimulate development and avoid rework and duplication; and revisit the education sector at primary and secondary levels. The ability to teach and train young Brazilians who can understand relevant and innovative AI problems, who have critical thinking skills, who can develop state-of-the-art solutions, and who focus on national solutions is an immense challenge. As a positive impact, we could see the development of national technology, focused on national issues and, at the same time, aligned with international needs and challenges. This impact should extend to various areas in the social and economic fields.

The ability to teach and train young Brazilians who can understand relevant and innovative AI problems, who have critical thinking skills, who can develop state-of-the-art solutions, and who focus on national solutions is an immense challenge.

ATTRACTING AI RESEARCHERS AND SCIENTISTS

Attracting AI experts to Brazil could accelerate the country's progress towards becoming a significant player in the field. Attracting specialists requires the establishment of international research centers in Brazil, similar to those existing in Europe and the USA. Cooperation between universities and research institutions could provide attractive project opportunities, facilitating the arrival of AI specialists. Brazil has a unique range of challenges that can attract innovative young professionals seeking to apply their knowledge. Establishing partnerships with global institutions could further serve as a beneficial strategy. Improving existing innovation hubs, technology parks, and startup ecosystems could also increase Brazil's appeal to foreign AI professionals.

It is recommended to implement a scholarship program for students in AI and related fields, encouraging them to act as tutors and innovation drivers in undergraduate and graduate courses. The value of the scholarships should be comparable to the market to encourage students to take on tutoring roles in undergraduate and graduate courses. It's a way to stimulate AI teaching and the development of innovative projects. Students who act as tutors often reach a higher level of understanding of the content being studied. This effect is valuable in a constantly evolving field like AI, where continuous learning is crucial.

VALORIZATION OF RESEARCH AND DEVELOPMENT IN AI

Brazil should protect and increase the workforce in universities, which is currently relatively small, albeit qualified. This initiative would generate more qualified individuals to understand, critique, and promote technological advancement. These professionals can serve as qualified educators and lead the application of AI in various scientific areas, focusing on solving Brazilian problems. It should substantially facilitate the establishment of regulatory frameworks and legislation that encourage researchers, professors, and universities to commercialize the results of their research through companies founded in the universities themselves (so-called technology-based startups). Despite efforts such as the Legal Framework for Science, Technology, and

Establishing multidisciplinary centers of excellence, particularly at universities that already have robust AI groups and expertise in other distinct areas of knowledge, could significantly boost the use and promotion of AI in various sectors.

Innovation[36] there are still significant regulatory risks for researchers who decide to generate wealth from their research, especially at public universities.

MULTIDISCIPLINARY R&D CENTERS IN AI

Establishing multidisciplinary centers of excellence, particularly at universities that already have robust AI groups and expertise in other distinct areas of knowledge, could significantly boost the use and promotion of AI in various sectors. This effort, combined with the expansion of these groups through the training of Brazilian specialists, would foster the advancement and use of AI. In this sense, one option is to create virtual centers that bring together experts from a specific region, stimulating collaboration and synergy regardless of institutional boundaries. This process could broaden access to technologies to a wider range of talents and specialties. In 2021, the Research Foundation of the State of São Paulo (Fapesp), the Ministry of Science, Technology, and Innovation (MCTI), and the Brazilian Internet Steering Committee (CGI.br) created a program for the establishment of Applied Research Centers (ARC) in AI,[37] focusing on the areas of health, agriculture, industry, and smart cities. This program could be extended to other applications and other universities.

COLLABORATION BETWEEN COMPANIES, UNIVERSITIES, AND GOVERNMENT

It is necessary to seek collaborations and partnerships between universities, companies, and the government in the context of personnel training and AI technology development to generate innovative products in various sectors of the economy. Multisectoral participation in the development of AI can bring significant benefits to the economy, especially in the formulation of automation strategies in industry and services tailored to the Brazilian reality.

AI IN EDUCATION

Technological progress is the main driver of human prosperity. Progress, however, does not happen automatically: It requires a real commitment from society for the necessary actions to be taken. A fundamental part of any technological advance is undoubtedly education. In this regard, in Brazil, in addition to the usual measures that should be adopted (such as promoting research and development in universities in related areas), AI should be used to accelerate education at all levels — from schools to universities. AI could be employed in education as a powerful tool, providing what is commonly referred to as an individual tutor for students. As demonstrated in the text *AI and education: Guidance for policy-makers* (UNESCO, 2021), and in the Khanmigo (TED, 2023; Coursera,

[36] Find out more: https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/noticias/2023/12/ministerio-lanca-portal-do-marco-legal-da-ciencia-tecnologia-e-inovacao#:~:text=It%20aims%20principally%20to%20strengthen%20the%20sustainable%C3%A1vel%20development%20of%20pa%C3%ADs

[37] Find out more: https://fapesp.br/16284/fapesp-anuncia-criacao-de-quatro-centros-de-pesquisa-aplicada-em-inteligencia-artificial

2023) and Wolfram projects,[38] AI has the potential to revolutionize teaching methodologies in all areas if properly planned and executed. In particular, in the field of computing, recent studies[39] show that the Copilot tool, based on LLM, increases productivity in software development and benefits developers and students during learning (Zingaro & Porter, 2024).

A recent debate (Rethinking Economics NL, 2021) between economist Daron Acemoglu (MIT) and journalist Martin Wolf outlined that the proper use of AI in schools should not replace educators, quite the opposite! The careful use of AI should enable teachers to devote more hours to nobler tasks, such as stimulating creativity in the classroom. Consequently, AI can stimulate the creation of jobs in education, generating new opportunities in a sector that is critical for society. This revolution, however, will not happen if the use of AI is inadequate. An example to be avoided is the use of technology to replace educators, handing over the task of teaching to less qualified individuals, and relying almost exclusively on automated processes. Harnessing the potential of AI depends on the full involvement of the public sector, especially in health and education applications. Society must be engaged with these changes, or we risk missing a narrow window of opportunity. On this journey, the public and private sectors must join forces to facilitate transformations.

EMPHASIZE EDUCATION AT ALL LEVELS

Prioritizing education at all levels and establishing partnerships with global education platforms are initiatives that, combined, can form an impactful strategy to accelerate the improvement of educational standards. By fostering global educational alliances, it is possible to catalyze progress in pedagogical methodologies. The AI system could, for example, analyze a student's performance to identify areas of strength and weakness, adjusting learning materials in real time to address topics according to their needs. This process can make learning more efficient and enjoyable, helping to keep students motivated and engaged. In a broader sense, this is a way of accelerating digital inclusion in society.

As an example, partnerships with Khanmigo or similar platforms (UNESCO, 2021) could be studied to provide Brazilian students with access to world-class educational resources. Collaboration can also allow courses to be customized to meet the specific needs of Brazilian students using local expertise. Finally, partnerships in the area can incorporate case studies of the reality in Brazil, focusing on issues of particular relevance to the Brazilian economy and regional specificities.

(...) AI can stimulate the creation of jobs in education, generating new opportunities in a sector that is critical for society. This revolution, however, will not happen if the use of AI is inadequate. An example to be avoided is the use of technology to replace educators (...).

[38] The Wolfram – Computation meets Knowledge project (https://www.wolfram.com/technologies/) demonstrates the potential of AI to revolutionize teaching methodologies.

[39] For more information, see: Peng et al. (2023); Shani (2023); and Kazemitabaar et al. (2023).

A safe regulatory environment is needed for professors and researchers who wish to contribute to the generation of wealth and a knowledge-based economy. This will only happen if there is legal certainty for entrepreneurial professors and researchers (...).

SIGNIFICANT, LONG-TERM INVESTMENTS IN AI R&D

We highlight the need for an immediate increase in funding from the government and the creation of mechanisms for the private sector to also increase investment in this technology. One possibility would be to explore the creation of programs or an agency along the lines of the Brazilian Company of Research and Industrial Innovation (Embrapii), focused on the development and adoption of AI. The agency's budget should be compatible with the investments made by other countries with a leading technological role — around R$1 billion per year for the next five years.

Again, it is worth pointing out that there are still no regulations that allow for the agile creation and operation of companies founded by professors and researchers, particularly in public universities. Such a scenario is not competitive internationally: Professors at public universities, particularly in North America, have ample regulatory facilities to undertake entrepreneurial ventures based on their research activities. The generation of wealth and high-level jobs in the country will not occur without a significant growth in technology-based companies. The case of the USA, both in Silicon Valley and in the regions of Boston, Austin, and around various universities, exemplifies that the engine of the new economy is the development of innovation-driven entrepreneurship. A safe regulatory environment is needed for professors and researchers who wish to contribute to the generation of wealth and a knowledge-based economy. This will only happen if there is legal certainty for entrepreneurial professors and researchers, as there is in the US, the UK, Israel, and countries in East Asia.

R&D IN AI PRIORITIZING THE SOLUTION OF BRAZILIAN PROBLEMS

Understanding where Brazilian companies have been using AI in their business can provide valuable ideas for the effective utilization of this technology. Sectors such as finance, health, education, retail, and agriculture are obvious candidates. To harness the full potential of AI, it is essential to integrate it into the educational curriculum. Universities should promote project-based learning, focusing on real-life case studies relevant to Brazilian social and business challenges. This approach would not only equip students with practical AI skills but also enable them to understand how AI concepts can be used to solve real-world problems. By engaging in such projects, students contribute to addressing urgent Brazilian problems while gaining practical experience with the technology. With this immersive, problem-solving approach to learning, new generations can be inspired to pursue careers in AI (and scientific careers in general) and its applications, further driving innovation and growth in this critical field.

REGULATION OF AI

Any regulation must be clearly communicated to the population, and in particular to the scientific community and the business community. To avoid delays in innovation and research progress, it is important that each restriction be carefully justified, and that society be informed why previous laws are not sufficient. Miscommunication can hinder the country's development,

leading to the abandonment of paths whose prohibition has not even been considered. Moreover, segments of the population may focus exclusively on the negative aspects of AI technology — aspects that are sometimes more akin to science fiction than practical reality. The scientific community should participate in the discussion process and be encouraged to make intensive efforts to disseminate information about the intended rules and controls.

The debate should be broad and not confined to a specific committee and must involve scientists of proven competence. The Brazilian scientific community has been developing research, innovating, and creating jobs over the past years. Therefore, we emphasize our recommendation: That all discussions on AI include scientists connected to the topic, both in the analysis of the various aspects of AI and in the evaluation of the consequences of intended regulations, including the planning of dissemination and clarification activities for society.

It is also expected that no regulation can limit or restrict the capacity for the development of Brazilian science and technology and that it is possible to innovate in controlled environments (sandboxes) in a simple and legally secure manner. Brazilian scientists in the field expect society, the government, and the private sector to have a perspective of understanding, freedom, and positivity towards the future of AI, with the certainty that this technology can provide much more gains than losses.

(...) our recomendation: That all discussions on AI include scientists connected to the topic, both in the analysis of the various aspects of AI and in the evaluation of the consequences of intended regulations, including the planning of dissemination and clarification activities for society.

DATA POLICY

Another key initiative for Brazil is data protection. The quality of the results obtained through AI techniques, such as predicting demand in different sectors and speeding up the accuracy of diagnoses, depends on the quality and consistency of the data used to train the algorithms. Therefore, there is significant interest from foreign companies and governments in accessing the databases that Brazil has in strategic areas. Examples of these databases include information from the Unified Health System (SUS), the Brazilian Agricultural Research Corporation (Embrapa), the Brazilian Federation of Banks (Federação Brasileira de Bancos [Febraban]), and the National Institute for Educational Studies and Research "Anísio Teixeira" of the Ministry of Education (INEP-MEC), as well as data on our biodiversity collected by companies and research institutions over the years. Therefore, it is essential to have a policy to regulate access to Brazilian databases and, in particular, the requirements for access to this data by foreign companies and governments. It is recommended that a national network of data centers be created, coordinated by a government institution.

Conclusion

The future of Brazilian society will be shaped by the choices that the government and society itself make in relation to AI. The sense of urgency regarding AI investments and the formulation of public policies emerges as crucial priorities worldwide, encompassing both developed and developing countries. Renowned

(...) we outlined fundamental principles to ensure that this technology not only transforms the economic landscape but also significantly contributes to the sustainable development of our nation, generating prosperity for all.

organizations such as the United Nations (UN), UNESCO, the World Economic Forum (WEF), the G20, the Organisation for Economic Cooperation and Development (OECD), and various other multilateral entities are united in considering AI technologies as a global imperative (10 Downing Street, 2023; OECD, 2021).

In this context, this report presents a series of recommendations aimed at boosting Brazil in the field of the use and scientific and technological advancement of AI. In addition, we outlined fundamental principles to ensure that this technology not only transforms the economic landscape but also significantly contributes to the sustainable development of our nation, generating prosperity for all (Ahmad et al., 2023; UNESCO, 2021; Sunak, 2023).

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Domain Report

The Regional Center for Studies on the Development of the Information Society (Cetic.br), department of the Brazilian Network Information Center (NIC.br), carries out monthly monitoring of the number of country code top-level domains (ccTLD) registered in countries that are part of the Organisation for Economic Co-operation and Development (OECD) and the G20.[40] Considering members from both blocs, the 20 nations with the highest activity sum more than 92.01 million registrations. In November 2023, domains registered under .de (Germany) reached 17.68 million, followed by the United Kingdom (.uk), China (.cn), and Netherlands (.nl), with 9.29 million, 8.16 million and 6.28 million registrations, respectively. Brazil had 5.30 million registrations under .br, occupying 6th place on the list, as shown in Table 1.[41]

[40] Group composed by the 19 largest economies in the world and the European Union. More information available at: https://g20.org/

[41] The table presents the number of ccTLD domains according to the indicated sources. The figures correspond to the record published by each country, considering members from the OECD and G20. For countries that do not provide official statistics supplied by the domain name registration authority, the figures were obtained from: https://research.domaintools.com/statistics/tld-counts. It is important to note that there are variations among the date of reference, although the most up-to-date data for each country is compiled. The comparative analysis for domain name performance should also consider the different management models for ccTLD registration. In addition, when observing rankings, it is important to consider the diversity of existing business models.

Table 1 – TOTAL REGISTRATION OF DOMAIN NAMES AMONG OECD AND G20 COUNTRIES

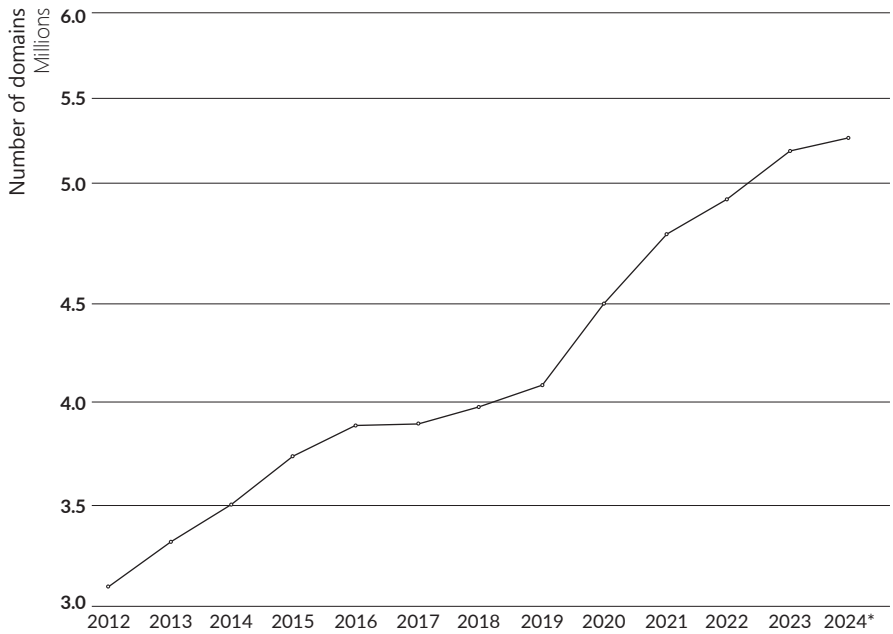
Position	Country	Number of domains	Date of reference	Source (website)
1	Germany (.de)	17,686,525	01/04/2024	https://www.denic.de
2	United Kingdom (.uk)	9,293,964	29/02/2024	https://www.nominet.uk/news/reports-statistics/uk-register--statistics-2024/
3	China (.cn)	8,164,091	01/04/2024	https://research.domaintools.com/statistics/tld-counts/
4	Netherlands (.nl)	6,283,044	01/04/2024	https://stats.sidnlabs.nl/en/registration.html
5	Russia (.ru)	5,589,498	01/04/2024	https://cctld.ru
6	**Brazil (.br)**	**5,304,202**	**31/03/2024**	**https://registro.br/dominio/estatisticas/**
7	Australia (.au)	4,251,146	01/04/2024	https://www.auda.org.au/
8	France (.fr)	4,138,319	12/01/2024	https://www.afnic.fr/en/observatory-and-resources/statistics/
9	European Union (.eu)	3,647,974	01/04/2024	https://research.domaintools.com/statistics/tld-counts/
10	Italy (.it)	3,499,574	31/03/2024	https://stats.nic.it/domain/growth
11	Canada (.ca)	3,392,586	01/04/2024	https://www.cira.ca
12	Colombia (.co)	3,257,076	01/04/2024	https://research.domaintools.com/statistics/tld-counts/
13	India (.in)	3,001,227	01/04/2024	https://research.domaintools.com/statistics/tld-counts/
14	Switzerland (.ch)	2,570,480	15/03/2024	https://www.nic.ch/statistics/domains/
15	Poland (.pl)	2,565,398	04/04/2024	https://www.dns.pl/en/
16	Spain (.es)	2,100,812	20/03/2024	https://www.dominios.es/dominios/en
17	United States (.us)	1,959,291	01/04/2024	https://research.domaintools.com/statistics/tld-counts/
18	Portugal (.pt)	1,823,528	01/04/2024	https://www.dns.pt/en/statistics/
19	Japan (.jp)	1,759,478	01/04/2024	https://jprs.co.jp/en/stat/
20	Belgium (.be)	1,730,746	01/04/2024	https://www.dnsbelgium.be/en

Collection date: April 1, 2024[42].

[42] With the exception of Poland, whose collection date is April 4, 2024.

Chart 1 shows the performance of .br since 2012.

Chart 1 – TOTAL NUMBER OF DOMAIN REGISTRATIONS FOR .BR – 2012 to 2024*



*Collection date: March 31, 2024.
Source: Registro.br
Retrieved from: https://registro.br/dominio/estatisticas

In March 2024, the five generic Top-Level Domains (gTLD) totaled more than 188.27 million registrations. With 157.58 million registrations, .com ranked first, as shown in Table 2.

Table 2 – TOTAL NUMBER OF DOMAINS AMONG MAIN gTLD

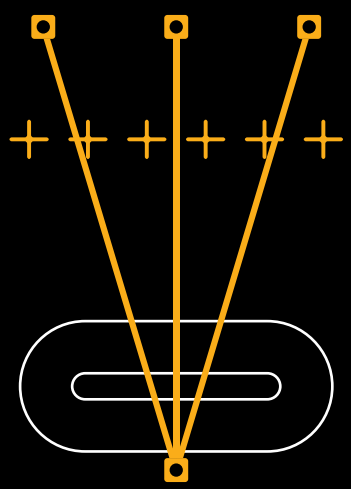
Position	gTLD	Number of domains
1	**.com**	157,586,968
2	**.net**	12,874,053
3	**.org**	10,825,850
4	**.info**	3,609,057
5	**.xyz**	3,381,682

Collection date: April 1, 2024.
Source: DomainTools.com
Retrieved from: research.domaintools.com/statistics/tld-counts

/Answers to your questions

The use of ARTIFICIAL INTELLIGENCE in Brazil

It is common to hear that Artificial Intelligence (AI) systems are becoming increasingly prevalent in our society. But where are they being used? Research from Cetic.br|NIC.br provides information on these uses in various sectors, such as enterprises, government organizations, and healthcare facilities, as shown in the results below.



Establishments in Brazil that have used AI technologies in the last 12 months:

ENTERPRISES[43]

10 to 49 employed persons	11%
50 to 249 employed persons	22%
250 or more employed persons	39%

TOTAL: 13%

FEDERAL AND STATE GOVERNMENT ORGANIZATIONS[44]

Executive Branch	20%
Legislative Branch	48%
Judiciary Branch	55%
Public Prosecutor's Office	50%

TOTAL: 24%

HEALTHCARE FACILITIES[45]

Public	3%
Private	13%

TOTAL: 10%

[43] Data from ICT Enterprises 2021 survey, by Cetic.br|NIC.br. Available at: https://cetic.br/en/tics/pesquisa/2021/empresas/H9/

[44] Data from ICT Electronic Government 2021 survey, by Cetic.br|NIC.br. Available at: https://cetic.br/en/tics/governo/2021/orgaos/H3/

[45] Data from ICT in Health 2022, survey by Cetic.br|NIC.br. Available at: https://cetic.br/en/tics/saude/2022/estabelecimentos/D5/

/Credits

TEXT

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ABOUT CETIC.br

The Regional Center for Studies on the Development of the Information Society – Cetic.br (https://www.cetic.br/en/), a department of NIC.br, is responsible for producing studies and statistics on the access and use of the Internet in Brazil, disseminating analyzes and periodic information on the Internet development in the country. Cetic.br acts under the auspices of UNESCO.

ABOUT NIC.br

The Brazilian Network Information Center – NIC.br (http://www.nic.br/about-nic-br/) is a non-profit civil Entity in charge of operating the .br domain, distributing IP numbers, and registering Autonomous Systems in the country. It conducts initiatives and projects that bring benefits to the Internet infrastructure in Brazil.

ABOUT CGI.br

The Brazilian Internet Steering Committee – CGI.br (https://cgi.br/about/), responsible for establishing strategic guidelines related to the use and development of the Internet in Brazil, coordinates and integrates all Internet service initiatives in the country, promoting technical quality, innovation, and dissemination of the services offered.

*The ideas and opinions expressed in the texts of this publication are those of the respective authors and do not necessarily reflect those of NIC.br and CGI.br.

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STRIVING FOR A BETTER INTERNET IN BRAZIL

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PHOTOS: RICARDO MATSUKAWA AND SHUTTERSTOCK