

Review Article
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A Calculus of Artificial Intelligences

Zhaohao Sun* and Francisca Pambel

School of Business Studies, PNG University of Technology, Lae 411, PNG, Papua New Guinea

ABSTRACT

Artificial intelligence (AI) was over; artificial intelligences (AIs) are booming around us. Artificial intelligence is significant for many people as a discipline, whereas artificial intelligences have benefited people, organizations, companies, and nations. This paper examines artificial intelligence and the evolution from AI to AIs. It presents a calculus of artificial intelligences, which covers AIs, AI computing, and AI entities (AIE) and AIE computing. This paper looks at business intelligences (BIs) as examples of AIs. This paper uses ChatGPT to answer how can we develop "Calculus of Intelligences". ChatGPT's answers and our remarks suggest that we should cooperate with AI to explore many new topics including "Calculus of Intelligences". The proposed approach in this paper might facilitate the research and development of AI, AIs, business intelligences, and business analytics.

*Corresponding author

Zhaohao Sun, School of Business Studies, PNG University of Technology, Lae 411, PNG, Papua New Guinea.

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Introduction

We are in the age of artificial intelligence (AI) [1-3]. However, artificial intelligence is no longer current. We are in the age of artificial intelligences (AIs) because artificial intelligences are booming around us. Artificial intelligence is significant for many people as a discipline, whereas artificial intelligences have benefited people, organizations, companies, and nations. This leads to two issues.

- Why are Artificial intelligences?
- What is the relationship between artificial intelligence and artificial intelligences?
- What is the calculus of artificial intelligences?

This paper presents a calculus of artificial intelligences. More specifically, this paper briefly looks at the evolution to AIs and examines AI. This paper then explores artificial intelligences. It presents a calculus of artificial intelligences (AIs), which covers AI computing, AI entities (AIEs), and AIE computing with various applications. This paper examines business intelligence (BI) and business intelligences (BIs) as examples of AIs. This paper uses ChatGPT to answer how can we develop "Calculus of Intelligences"? ChatGPT's answers and our remarks advise that we must cooperate with AI to develop or explore many new topics, including "Calculus of Intelligences" [4].

The rest of this paper is organized as follows: Section 2 looks at the evolution of artificial intelligence. Section 3 looks at artificial intelligence. Section 4. examines artificial intelligences. Section 5 presents a calculus of artificial intelligences. Section 6 examines BI and BIs. Section 7 uses ChatGPT to answer how we can develop "Calculus of Intelligences", and provides our remarks on

the relationship between AI and our research. The final section ends this paper with a few concluding remarks and suggestions for future work.

Evolution of Artificial Intelligence

This section analyzes the evolution of artificial intelligence. Alain Turing published his seminal paper, Computing Machinery and Intelligence, in 1950 [5]. John McCarthy, a mathematics professor at Dartmouth, defined AI as the "science and engineering of making intelligent machines" in 1956 [6,7]. His definition can be updated as science, engineering, technology, and systems of making and managing intelligent entities, covering platforms, machines, and systems. From that time on, AI has become one of the most significant forces affecting human beings, machines, systems, and platforms. AI has been one of the most rapidly developing fields in the last seven decades. We are currently immersed in the age of AI. AI directly focuses on intelligence, wisdom, and mind. However, since the late 1950s, AI researchers have found that knowledge-driven intelligence is important because of the development of expert systems and knowledge base systems. In the past decade, data intelligence has become more important because of machine learning's resurgence and deep learning development, thanks to the inception of ChatGPT and DeepSeek [8]. There are many types of intelligences, for example, the human bodily intelligences consisting of hearing intelligence, writing intelligence, and moving intelligence, which focus on the development of human-centered AI [9].

Briefly, AI is a subfield of computer science and data science, concerned with symbolic reasoning, problem-solving, and natural intelligences [10,11,12]. Technically, AI is concerned with imitating, extending, augmenting, amplifying, automating, and optimizing the intelligent behaviors of human beings [13,]. AI attempts not only to understand how humans think, understand, write, learn, listen, act, and move rationally and smartly, but

also to build intelligent entities that can think, write, perceive, understand, predict, and manipulate a world [14].

Jenkins, et al. stated that “the history of AI has included several waves of ideas” The first wave, from the 1950s to the 1980s, focused on logic and symbolic hand-encoded representations of knowledge, the foundations of so-called “expert systems”. The second wave, starting in the 1990s, focused on statistics and machine learning, in which, instead of hand-programming rules for behavior, programmers constructed “statistical learning algorithms” that could be trained on large datasets. In the last decade, some AI research activities have largely focused on deep learning in machine learning. AI has experienced a resurgence recently because the increasing computing power, models, algorithms, and chips have become increasingly refined [15]. Other reasons are that data-driven and market-oriented AI are becoming popular products around us; AI on social media has blossomed in these communities [16]. The current wave is that AI has been ubiquitous in the market. Market-driven AI is aimed at machines, systems, platforms, apps, and tools.

Artificial Intelligence

This section reviews AI and explores AIs as next-generation intelligences.

Intelligence is not only a lasting topic for computer science, AI, intelligence computing, BI, and intelligent analytics, but also an exciting topic for industries, organizations, and businesses.

AI has facilitated the development of intelligent services, intelligent manufacturing, intelligent systems, intelligent chips, and intelligent analytics [17]. BI has improved competitive business and marketing performance, supported management decision-making of organizations, and produced trillion-level enterprises or industries such as Google, Amazon, Alibaba, and Meta. These industries continue to dominate frontier AI research and development; Generative AI investments have skyrocketed because of ChatGPT and DeepSeek. China is dominating industrial robotics: In 2013, China’s installations accounted for 20.8% of the global total [18]. A number of companies are branding their products as AI products. Many social media brands are created as AI products and services. For example, ChatGPT-4, Gemini, and Claude are impressively multimodal: They can generate fluent text in dozens of languages, process audio, and even explain memes.

Artificial intelligence has been playing a significant role in making AI ubiquitous and upgrading economies and industries to intelligent ones. An artificial intelligence entity (AIE) is an intelligent entity within a system, app, platform, or tool. For instance, Nvidia GPU chips, DeepSeek, and ChatGPT are examples of AIE. Data, intelligences, and analytics are the most important attributes of the AIE. Currently, data, analytics, and intelligences and their integration are also at the frontier for revolutionizing our work, life, business, management, and organization, as well as healthcare, finance, e-commerce, and web services [19]. Big data has become one of the most unprecedented and ever-increasing frontiers for innovation, research, and development in the computer industry and business. Big data analytics, advanced analytics, and modern analytics have drawn increasing attention in academia, industry, and government [20]. Artificial intelligence entities are becoming a core business and analytic competency to transform business processes, reconfigure workforces, optimize infrastructure, and blend industries [21]. However, the current AI is a mixed intelligence and market-driven, and so is useful for AI research and development prompting such questions as.

- What is the next trend in artificial intelligence?

- What is the relationship between artificial intelligence and artificial intelligences?
- How can we examine an artificial intelligence entity?
- What is the relationship among artificial intelligence entities, data, analytics, and intelligences?

All these questions need to be addressed by academia, industries, and people in the near future.

Artificial Intelligences

This section explores artificial intelligences. The core ideas are artificial intelligence (AI) was over. Artificial intelligences (AIs) are booming around us.

Multiple Intelligences

Professor Howard Gardner provides the theory of Multiple Intelligences (MI) [22]. This consolidates the relationship between natural intelligences and artificial intelligences. He also changes human intelligence into human intelligences.

Gardner states that the single word ‘intelligence’ is fundamentally limited and misleading. This is not only right for the theory of multiple intelligences. It is also right for (natural) intelligences in AI. For example, how many intelligences are in our own body? There are at least 12 natural intelligences. Furthermore, from a technological viewpoint, each of the 12 natural intelligences of our own body needs many different artificial intelligences (AIs) to imitate, augment, simulate, and optimize natural intelligences as we realized. Many AIs are used to realize intelligences of our human body. In other words, the relationship between a human intelligence and many AIs is one to many (1:m). The relationship between many AIs and human intelligences are many to many (m:m).

AI and AIs in Books

Many books have used AIs, although they have not explained why AIs and AI are different. For example, Kissinger, et al [23]. Bostrom [20], and Mollick [4] have used AIs in their books. Sun differed AIs from AI based on the idea of Gardner’s Theory for Multiple Intelligences (MI).

Sun discussed intelligence, mind, and wisdom in his book [3]. In fact, the national and international intelligence, mind, and wisdom are very important as they are for a country, community, organization, and multinational corporation.

In such a way, we have big intelligence, big mind, and big wisdom. Furthermore, intelligence, mind and wisdom were mentioned Kissinger’s book (Kissinger, Schmidt, & Huttenlocher, 2022).

There are over 60,000 results for “intelligence” rather than “intelligences” based on the search of Amazon’s books. That is, neither intelligences nor artificial intelligences are available on the book list of Amazon. Intelligence and artificial intelligences dominate the research and applications in the market.

We will argue that AIs are based on the Multintelligence and a set of intelligences in Section 5.

Artificial Intelligences from the Scholars

Google Scholar search for “artificial intelligence” and “artificial intelligences” found 4,930,000 and 18,100 publications on August 23, 2025. This implies that artificial intelligence plays an important role in research and development, and furthermore, artificial intelligences have also drawn important attention recently.

Of 18,100 publications on artificial intelligences, are “legal personhood artificial intelligences, artificial intelligences moral agents, artificial intelligences robots, artificial intelligences suggestive drawing, artificial intelligences digital minds”. Artificial intelligences robots are important for artificial intelligences. Artificial intelligences robots have 47 results on August 23, 2025. Artificial Intelligences, Robots, Bio-engineering and Cyborgs: New Challenges for Theology? is a brief research [24]. Then we analyzed the first 100, ranked by Google Scholar search, and found that:

- No authors explain AIs.
- From the perspective of psychology and philosophy, Brożeka and Janik address the question of whether artificial intelligences can be moral agents based on internal, external, and moral agency [25]. The paper concludes that machines cannot be considered moral agents. However, the research only mentioned “existing artificial agents, as well as the future ones which are constructed within the same ‘architectural’ paradigm, and their relationships with the external and internal conditions of moral agency. However, there are no relationships with artificial intelligences.
- Sotala surveys four categories of factors that might give a digital mind, such as an upload or an artificial general intelligence, an advantage over humans [26]. It seems that no real exploration into artificial intelligences has been conducted, although artificial intelligences has not played a significant role in this research.
- Fox uses multi-Intelligence (MI) to combine natural and artificial intelligences in hybrid beings and systems [27]. From the references of Fox’ research, we have not found the AIs. Even so, Fox frames AI as a contributor to multi-intelligence (MI) in the setting of hybrid beings and/or systems. Fox’s idea leads us to extend natural intelligences and artificial intelligences and how to develop natural intelligences with artificial intelligences. Intelligences consist of natural and artificial ones. What Professor Garder researched is natural intelligences of our human body. What we explore are artificial intelligences.
- Levin considers artificial intelligences as a bridge toward diverse intelligence and humanity’s future [28].

Overall, many scholars have used AIs to describe AI-related machines, systems, platforms, and apps. There is no mention yet about a series of theories on what AIs are. There is one possibility for defining artificial intelligences as diverse human minds; however, human minds are at a meta (intelligence) level.

A Definition of Artificial Intelligences

To define artificial intelligences, we first define an ICT infrastructure, entity, and attribute.

An ICT infrastructure is a set of physical products, devices, hardware, and software required to the business of individuals and organizations [29].

The Components of ICT Infrastructure Comprise [26]:

- Computer hardware platforms,
- Operating system platforms,
- Enterprise software applications,
- Data management and storage,
- Knowledge management and storage systems,
- Networking/telecommunications platforms,
- Internet platforms and cloud platforms,
- Consulting system integration services.

An ICT infrastructure and a digital infrastructure are used interchangeably.

Based on the dictionary of Merriam-Webster entity is

- a: being, existence, especially: independent, separate, or self-contained existence
- b: the existence of a thing as contrasted with its attributes
- something that has a separate and distinct existence and objective or conceptual reality[30].

Then we use entity as something that has separate and distinct existence. In a database, an entity represents a real-world object [31]. An entity can be a human being, a vehicle, a building, or an enterprise.

Entities are an entity set, that is,

Entities = {x| x is entity in the real world }.

For example, data mining, robots, databases, and information systems are the entities. The entities comprise natural entities, environmental entities, physical entities, biological entities, social entities, and organizational entities. For example, human beings, machines, systems, platforms, and apps are parts of entities. There is intelligence in some entities. For example, Peter has intelligence. Some machines have their own intelligences. Some systems have their own intelligences. With the AI’s development, more and more entities have their own intelligences. Attributes are characteristics of entities. For example, a student’s attributes include the attributes of Stu_Name, Stu_FName, and Stu_age. The relationship between an entity and its attributes is 1:m. Attributes can be classified as simple and composite. A simple attribute is an attribute that cannot be divided. For example, Peter’s age, and surname, which cannot be separated. A composite attribute is an attribute that can be further subdivided to yield additional attributes. For example, the attribute intelligence can be divided into thinking intelligence, understanding intelligence, learning intelligence, connecting intelligence, and sharing intelligence. Now we can define artificial intelligences in terms of intelligence, infrastructure, entity, and attribute. Artificial intelligences are defined as “intelligences that entities possess based on the ICT infrastructure”. For example, artificial intelligences are intelligences that humans, machines, and systems possess based on the ICT infrastructure consisting of a set of intelligent systems, technologies, and tools within various services. Humans can have artificial intelligences such as data intelligences, information intelligences, knowledge intelligences, system intelligences, machine intelligences, platform intelligences, app intelligences, cloud intelligences, sharing intelligences, connecting intelligences, and service intelligences. Nvidia, Microsoft, Meta, Amazon, Google, ChatGPT, Baidu, Tencent, Alibaba, Huawei, and DeepSeek provide above-mentioned intelligences and services for billions of people; intelligences as a service (IaaS) are ubiquitous to individuals, organisations, and governments. Humans have hearing intelligences, speaking intelligences, writing intelligences, tasting intelligences, moving intelligences, and more. Each of them has been implemented using a set of intelligent machines, systems, technologies, platforms, tools, and services. For example, WeChat and WhatsApp provide integrated intelligences of hearing, speaking, and writing to billions of people based on IaaS. Moving intelligences have been realized using all technologies since the Industrial Revolution. For example, industrialization, automation, digitalization, servitization, cloudization, intelligentization, and optimization have facilitated moving intelligences of vehicles, trains, and airplanes.

A Framework for Defining Artificial Intelligences

This section delves into a framework for defining Artificial Intelligences.

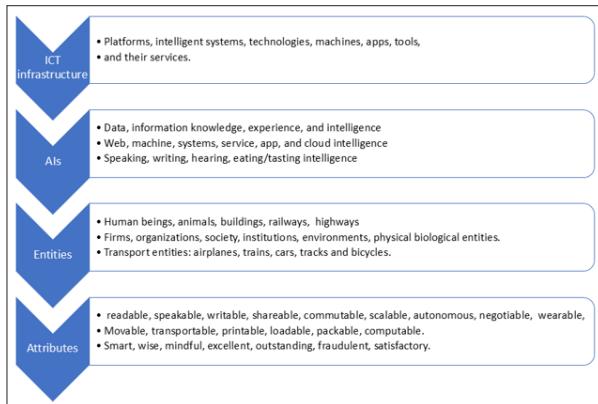


Figure 1: A framework for defining artificial intelligences

In Figure 1, the framework consists of the ICT infrastructure, AIs, entities, and attributes. This section delves into this framework for defining Artificial Intelligences. AIs are made up of data intelligence, information intelligence, knowledge intelligence, experience intelligence, web intelligence, machine intelligence, systems intelligence, platform intelligence, robot intelligence, service intelligence, app intelligence, and cloud intelligence. AIs also comprise human intelligences, such as speaking intelligence, writing intelligence, hearing intelligence, eating intelligence, and tasting intelligence.

Entities consist of humans, animals, buildings, railways, highways, firms, organizations, societies, institutions, environments, physical entities, biological entities, and transport entities. Transport entities comprise rockets, ships, airplanes, helicopters, drones, trains, cars, trucks, tractors, and bicycles.

The most important entities consist of agriculture, industry, science and technology, defence, and service. Each of them will comprise more sectors, and will become intelligent entity for a country. We will discuss each of them in future work.

Platforms and ecosystems are used interchangeably. A platform is the underlying ICT infrastructure or mechanism that enables interactions among many different systems, apps, machines, and tools. An ecosystem is the broader network of interconnected users, developers, and complementary services such as machines, systems and tools that leverage a platform to coordinate activities.

ICT infrastructure consists of a set of intelligent systems, technologies, machines, robots, apps, and tools with various services and applications. Therefore, in the framework, ICT infrastructure is used to enable entities to possess AIs. At the same time, AIs will also impact entities to develop new intelligent systems, technologies, apps, tools, and services with various applications.

The relationship between AIs and entities is 1:m. For example, an entity consists of humans, comprising speaking intelligence, writing intelligence, hearing intelligence, eating intelligence, and tasting intelligence.

The Attributes Consist of the Characteristics of an Entity:

- Readable, speakable, writable, shareable, commutable, scalable, autonomous, negotiable, wearable;
- Movable, transportable, printable, loadable, packable, computable.
- Smart, wise, mindful, excellent, outstanding, fraudulent, and satisfactory

Intelligent agents are AI entities. Autonomy and independence are two important attributes for intelligent agents. Intelligent analytics is significant for developing AI entities. Intelligent analytics are an agent system that is descriptive, diagnostic, predictive and prescriptive (DDPP). In such a way, this intelligent analytics completely realizes DDPP intelligently.

The relationship between an entity and attributes is 1: m. that is, entity have many attributes in the AI systems.

Finally, let A is a set of all intelligent attributes. S is a set of characteristics of intelligences. D is a set of all digital words for realizing AIs. Then we have.

$A \supseteq S$. That is, a set of all intelligent attributes include a set of characteristics of intelligences

$D \supseteq A$. That is, a set of all digital words for realizing AIs include a set of all intelligent attributes.

The above propositions are the basis for realizing AIs based on ICT infrastructure.

A Calculus of Artificial Intelligences

Calculus is a branch of mathematics that “deals with rates of change” [32]. Calculus is also used to name specific methods of calculation or notation, as well as some theories and operations, such as probability calculus, relational calculus, and propositional calculus [33]. This section uses the latter annotation of calculus for this research and presents a calculus of artificial intelligences. The remainder of this section is organized as follows. Section 5.1 provides the foundations of AI and AIs. Section 5.2 looks at AI and AIs. Section 5.3 explores intelligences and multi-intelligences. Section 5.4 explores AI, AIs, and AIEs. Section 5.5 examines the Internet of Intelligences.

Introduction

Calculus has been studied in AI. For example, a unifying action calculus encompasses situation calculus, fluent calculus, and event calculus. It not only facilitates comparisons and translations between specific approaches; unifying action calculus also allows to solving interesting problems for various calculi [34]. Sun proposed a calculus of intelligent analytics and a calculus of intelligent business analytics [3]. He argues that the calculus of intelligent analytics is a bridge connecting big data analytics, AI, AIs, BI, and other intelligent technologies. With the evolution of AI to AIs, what is the calculus of artificial intelligences? This research will address it and present a calculus of artificial intelligences.

AI and AIs

Artificial Intelligences (AIs) are made up of data intelligence, knowledge intelligence, experience intelligence, wisdom intelligence, analytics intelligence, big data intelligence, understanding intelligence, learning intelligence, to name a few. For example, machine learning aims to develop learning intelligence. Expert systems aim to improve knowledge intelligence. Big data analytics aim to provide analytics intelligence and insights to individuals and organizations. In such a way, we can easily

understand meta intelligence as intelligence about intelligence.

We can differentiate intelligence from intelligences. We emphasize learning, understanding, thinking, connecting, and sharing as keys to intelligence. We also highlight collective intelligence, cooperation, collaboration, negotiation, and bargaining as intelligences, as illustrated in Table 1 [35,36].

Table 1: Artificial Intelligence and Artificial Intelligences

Intelligence	Intelligences	Remarks
Learning	Collective Intelligences	for collective work
Understanding	Cooperation	Cooperation intelligences
Thinking	Collaboration	Collaborative intelligences
Connecting	Negotiation	Negotiation intelligences
Supervising	Supervision	Supervision intelligences
Sharing	Bargaining	Bargaining intelligences

We will look at three of them in Table 1. Below.

Collaborative Intelligences

Collaboration is working with others to achieve shared and explicit goals. Collaboration and teamwork are more key for any team and organization. Tools and technologies for collaboration consist of virtual meeting systems (telepresence), cloud collaboration services (Google Drive, Google Docs, etc.), Microsoft SharePoint, and enterprise social networking tools such as Zoom software, and Moodle; all these facilitate the development of collaborative intelligences of individuals and organizations.

Supervision Intelligence

Agent supervisors are specialized agents that coordinate, manage, and control other agents to complete a set of jobs. For example, in a content creation system, an IT supervisor can supervise his IT agents to create all IT subjects for IT students. From a multiagent system (MAS) perspective, supervision is an integration of coordination, management, and control. In other words, Supervision intelligences are an integration of coordination intelligence, management intelligence (including decision intelligence), and control intelligence.

Data Intelligence and Knowledge Intelligence

Machine learning is a data intelligence-driven technique. ChatGPT is a data intelligence technique that can bring about the same knowledge intelligence. DeepSeek is also an intelligent tool for providing data intelligence and knowledge intelligence to customers.

Based on Gartner's research on the Hype Cycle for Artificial Intelligence, Generative AI (GenAI) receives great attention of the hype when it comes to AI [37]. However, GenAI has yet to deliver on its anticipated business value for most organizations. GenAI has passed the peak of inflated expectations. Maybe it also reflects that another winter of AI will be upon us within a year. Similarly, the general problem solver was not very successful in 1957 [38]. GenAI also faces some "general" challenges, including ethical and societal concerns, and nefarious uses like deep fakes and disinformation.

The composite AI is as follows:

- Composite AI lays the foundation for future AI architectures. Composite AI represents the next phase in AI evolution. The original concept is a hybrid AI. Composite AI combines AI methodologies, such as machine learning, natural language

processing, and knowledge graphs, to create a more adaptable and scalable solution. For instance, integrating knowledge-based (rule-based) systems with machine learning allows enterprises to process unstructured data, thereby enhancing their ability to derive insights from diverse datasets.

- AI computing has become famous because of the boom of Nvidia. Then we have

$\text{AI Computing} = \text{AI science} + \text{AI engineering} + \text{AI technology} + \text{AI systems} + \text{AI} + \text{AI services}$.

AI Computing is computing from AI, whereas AIE Computing is computing from AIE. AIE is the abbreviated term of an AI entity. Then we have

$\text{AIE Computing} = \text{AIE science} + \text{AIE engineering} + \text{AIE technology} + \text{AIE systems} + \text{AIs} + \text{AIE services}$.

- AI engineering has been mentioned in many books. For example, one of the fundamental skills in AI engineering is writing great prompts [39].
- AI engineering and knowledge graphs. AI engineering approaches, such as Data Ops, Model Ops, and DevOps, make it possible to deploy models into production in a structured, repeatable factory-model framework. Knowledge graphs are machine-readable representations of the physical and digital worlds.
- Besides the above-mentioned, the hype cycle for AI also includes autonomic systems, quantum AI, embodied AI, multiagent systems, decision intelligence, and prompt engineering. This consists of IoT (the Internet of intelligent everything). Furthermore, this also means that multiagent systems have been moving towards the market rather than at the theoretical level. We will look at the multiagent systems in future work.

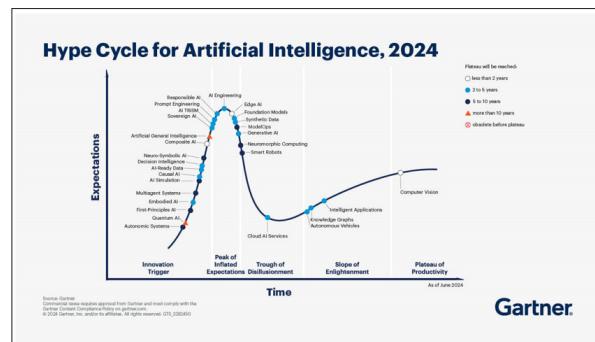


Figure 2: Gartner Hype Cycle for AI 2024

Furthermore, one agent cannot dominate all in AI, but there are millions of AI agents; They will work together to complete almost all delegated tasks [40,41].

Intelligences and Multi-Intelligences

A model of artificial intelligences was introduced based on Multi-intelligence (MI) hybrid beings and systems, as illustrated in the following Figure 3.

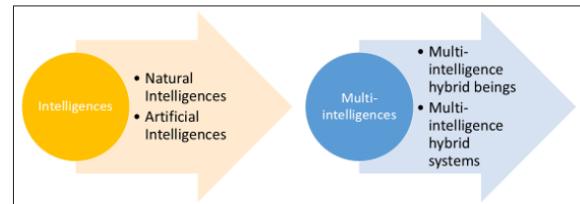


Figure 3: Intelligences and multintelligences

In this model, intelligences have been classified into natural intelligences and artificial intelligences. Human intelligence is an example of natural intelligences. Machine intelligence is a kind of artificial intelligences. Multi-intelligences have been classified into multi-intelligence hybrid beings and multi-intelligence hybrid systems. More generally, natural intelligences are composed of human intelligences, animal intelligences, social intelligences, environmental intelligences, and business intelligences [42]. Fox has not specifically mentioned artificial intelligences in his research [24]. However, the intelligences contributed to multi-intelligences, which consist of multi-intelligence hybrid beings and multi-intelligence hybrid systems. Multi-intelligences were used for exploring human intelligences since 1980. Human intelligences have even intelligences. A human body has at least 12 natural bodily intelligences [3].

Based on Merriam-webster dictionary, being has the following meaning:

A: the quality or state of having existence. Example: social events and natural events.

B: Something that actually exists: Example: life and entity

C: A living thing. Example: person and animal [43].

Fox has covered all beings except the systems [24]. Therefore, hybrid beings are related to human beings, animals, and machines. Multintelligences have the following characteristics listed in Table 2.

Table 2: Mult intelligences and their Characteristics

Multintelligences	Characteristics	Examples
Multintelligences	includes the full range of natural and artificial intelligences, which are defined in fundamental terms, such as self-awareness, robust adaptation, and problem solving.	Human bodily intelligences, Intelligence of intelligent multi-agent systems.
Multintelligences	considered in terms of whole systems of causal mechanisms and causal contexts encompassing the full range of variables that can contribute to intended and unintended consequences	Intelligences from a group of robots working in the production line-Robotic process automation.
Multintelligences	encompasses hybrid beings and hybrid systems having emergent properties that can be more than, and different from, the various types of intelligence, which they are comprised of.	Intelligences from intelligent enterprise systems, for example, supply chain intelligence and customer intelligence.

Robotic process automation (RPA), also known as software robotics, uses intelligent automation technologies to perform repetitive office tasks of human workers, such as extracting data, filling in forms, moving files, and more [44,45]. RPA uses rule-based expert systems to perform business process activities at a high volume, freeing up human resources to prioritize more complex tasks. RPA enables CIOs and other decision makers to accelerate their digital transformation efforts and generate a higher return on investment (ROI) from their staff.

The difference between RPA and AI is that RPA is a process-driven and rule-based system; RPA can only follow the rule-based processes. AI combines cognitive automation, rule-based expert systems, machine learning (ML), natural language processing (NLP), reasoning, hypothesis generation, and analysis to create multintelligences and integrated intelligences. Therefore, AIs are at least knowledge-based and data-based intelligences. AI bots integrate expert systems and machine learning to recognize patterns in data and make decisions.

From AI via AIs to AIEs

The above model can be extended into the following model: from AI via Artificial intelligences to AIEs, as illustrated in Figure 4.

Human intelligence has been studied in artificial intelligence. Both have been extended to intelligences, which consist of natural intelligences and artificial intelligences. Natural intelligences and artificial intelligences have been extended into multi-intelligences. Multi-intelligences have been classified into multi-intelligence hybrid beings and multi-intelligence hybrid systems. They then are extended into artificial Intelligence entities (AIEs). AIEs have been classified into AIE apps, AIE machines, AIE systems, AIE platforms. It is interesting to study these based on Figure 4.

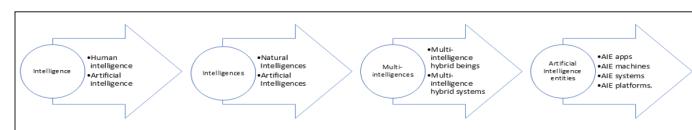


Figure 4: From AI via AIs to AIEs

Therefore, from AI to AIs, intelligences are the real phenomena in the intelligence world, not only in human intelligences, but also in AIs. If humanity has its world, what is the intelligence world? The intelligence world consists of a number of intelligences. AIs will bring AIEs. More generally, AIEs are from AIE computing, that is, AIE computing = AIE science + AIE engineering + AIE technology + AIE systems + AIE services + AIE machines + AIE machines + AIs.

The Internet of Intelligences

When discussing intelligences with various applications, we must explore the Internet of AIs. That is, The Internet of AIs consists of many different AIs which interacted with many different intelligent systems or agents. In other words, the Internet of AIs has been reflected by the integration of many Internets of intelligent entities, such as different intelligent systems or agents, as shown in Figure 5. In other words, the Internet of AIs will be implemented by the Internet of intelligent entities, such as different intelligent systems or multiagent systems. At the same time, the Internet of intelligent entities, such as different intelligent systems or multiagent systems, will produce the Internet of AIs.

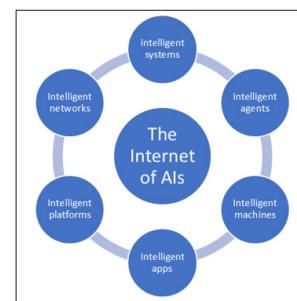


Figure 5: The Internet of AIs and the Internet of Intelligent Entities

The Internet of Everything (IoE) expands the Internet of Things (IoT) by connecting people, processes, big data, and things to create a more integrated and intelligent network. Then we have the equations.

$$\text{IoE} = \text{IoT} + \text{IoP} + \text{IoS} \quad (1)$$

We apply intelligent as an operation on both sides of (1), to have $\text{IoIE} = \text{IoIT} + \text{IoIP} + \text{IoIS}$. (2)

Where IoIE = The Internet of intelligent everything, IoIT as The Internet of intelligent things, IoIP = The Internet of intelligent people, IoIS = The Internet of intelligent services.

Furthermore, we have the Internet of intelligent entities as a part of IoIE , which produces the Internet of AIs. That is, $\text{IoAIEs} \subset \text{IoIEs}$ produce IoAIs (3)

Where IoAIEs = the Internet of AI entities, IoIEs = the Internet of intelligent entities and IoAIs = the Internet of AIs.

From Business Intelligence to Business Intelligences

Intelligences are also important in BI and BIs. This section looks at business intelligence and business intelligences, and discusses the relation between business intelligences and artificial intelligences.

Commerce refers to buying and selling. Business consists of all activities related to buying and selling. Business intelligence (BI) was first coined by Luhn in 1958 when he developed a business intelligence system at IBM. Business intelligence BI was then promoted by Dresdner since 1989. Business intelligence is the intelligence for making money from humans, machines, and systems in business activities using a set of machines, systems, technologies, and techniques. BI has important technology for developing business technologies and systems. The most fundamental technologies of BI consist of data mining, data warehousing, and data analytics [3].

Only some indulge BI while many have already used BIs. That is, a business may consist of multiple intelligences, for example, BI consists of financial intelligence, agile business intelligence, commercial intelligence, competitive intelligence, market intelligence, social intelligence, mobile business intelligence, retail intelligence, real-time intelligence, visual business intelligence, location intelligence, sales intelligence, product intelligence, and more. In reality, every business action requires business intelligences (BIs) to promote the business activities.

BIs are all the intelligences for making money from business humans, machines, systems, and platforms using a set of intelligent machines, intelligent systems, intelligent technologies, and intelligent techniques.

Therefore, there are a number of business intelligences that need to be imitated, augmented, and simulated using intelligent systems, such as market analytics and intelligence, e-commerce analytics and intelligence, Supply Chain analytics and intelligence, and more.

The relationship between AIs and BIs is that the BIs are the applications of AIs in the business domain, whereas AIs are the generalization of BIs, as shown in Figure 6. Similarly, BI is the application of AI, whereas AI is the generalization of BI.

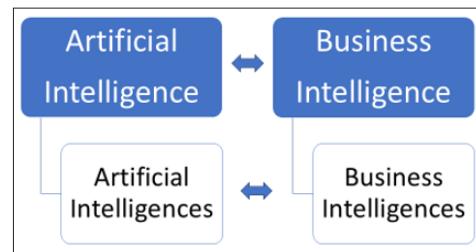


Figure 6: AIs and BIs

Intelligences are also Important from BI and BIs. We will discuss discuss BIs from BI in future work.

How can we Develop "Calculus of Intelligences"

This section uses ChatGPT to answer questions on how we can develop "Calculus of Intelligences" on September 19, 2025. The followings are ChatGPT's answers and our remarks. The first part is the introduction of ChatGPT to our question.

Introduction

That's a fantastic ambition-creating a Calculus of Intelligences would mean trying to formalize how different kinds of intelligence, which interact, evolve, and produce outcomes. Since it's an uncharted field, you'll be founding it rather than following a set playbook. Here's a structured way to develop it:

- Define the domain of intelligences
- Establish units and variables
- Establish units and variables
- Introduce operations (derivatives & integrals of intelligence)
- Create test models
- Philosophical & ethical layer
- Prototype the framework
- Give it formal structure

In what follows, we will provide ChatGPT's answers, and our remarks for each of them.

Define the Domain of Intelligences

Decide which "intelligences" you want to model:

Human cognitive dimensions (logical, emotional, social, creative, embodied).

Artificial intelligence (symbolic AI, machine learning, reasoning systems).

Collective intelligence (groups, networks, swarms, societies).

Remark: *Cooperation, collaboration, and cooperation as c3 based on communication and interaction are also important for collective intelligences in multiagent systems.*

Ecological/Systemic Intelligence (how Environments Self-Regulate).

Remark: *These are very helpful. We will discuss each of them carefully. Systemic intelligence has been discussed in many research fields such as Sun's [3,17].*

First Question: Are you measuring kinds of intelligence or agents with intelligence?

Remark: This is also helpful. We really believe that intelligence is computable, at least we have not found the computing of intelligences, which is our research in future work. We cannot get a simple formula of Albert Einstein ($E=MC^2$), but we cannot scare about lengthy formula for intelligences either. At least we will try to do soon.

Establish Units and Variables

To build a calculus, you need variables. Some candidates:

Capacity (raw ability, e.g., IQ-like metrics or ML benchmarks).

Efficiency (resources consumed vs. tasks accomplished).

Scope (range of problems addressed).

Adaptability (rate of learning/change).

Synergy (how well one intelligence enhances another).

Each of these could be thought of as a function over time.

Remark: We have not used them at the moment. We also believe that this is not our topic for study in this paper and near future. Even so, we like to directly measure intelligence and intelligences.

Introduce Operations (Derivatives & Integrals of Intelligence)

Derivative of Intelligence: Rate of change of capability.

Example: $d(\text{Intelligence})/dt$ = how fast a system learns.

Integral of intelligence: Accumulated effect over time.

Example: total contribution of a group's intelligence over a project's lifespan.

Interaction Terms

Multiplicative (Synergy) → Two intelligences produce more than the sum.

Competitive (Inhibition) → One suppresses the other.

This is where it starts becoming a real calculus.

Remark: No. We cannot accept this answers at the moment. However, we operate intelligences Arithmetically and logically. For example, we measure intelligence as the combination between knowledge and reasoning, that is, $\text{Intelligence} = \text{knowledge} + \text{reasoning}$.

Create Test Models

Simple dyad: Model how human intelligence and AI intelligence together solve a problem.

Variables: human adaptability, AI speed.

Equation: $\text{Output} = H(t) + A(t) + k \cdot H(t) \cdot A(t)$, where k is synergy coefficient.

Collective swarm: Use differential equations to describe how many agents contribute to a solution as a function of communication and error rate.

Remark: we also hope to use expectation as the human intelligence. We also believe more lengthy formula is needed to operate them.

Philosophical & Ethical Layer

Ask: what is the purpose of this calculus?

Prediction (e.g., AI-human collaboration outcomes).

Optimization (e.g., how to maximize group creativity).

Balance (e.g., weighing machine vs. human decision-making authority).

You may want to mirror Bentham's hedonic calculus, but for intelligence trade-offs.

Remark: We have studied Bentham's hedonic calculus. We have not used it for our research on Calculus of Intelligences at the moment.

Prototype the Framework

Start with toy models (2–3 intelligences interacting).

Use simulations: agent-based models, system dynamics.

Iteratively refine until you have a set of formal rules that resemble a calculus.

Remark: We do not develop it at the moment. We first explore intelligence, intelligences, artificial intelligences, and AIEs in order to develop the calculus of intelligences.

Give it Formal Structure

Draft axioms (what is always true about intelligences?).

Define theorems (results that can be proved from the axioms).

Establish symbolic notation (so it feels like an actual calculus). In other words, you'd be doing for mind dynamics what Newton and Leibniz did for physical dynamics.

Would you like me to sketch a first "toy calculus" model — maybe with just two interacting intelligences (human + AI) to illustrate what the math could look like?

Remark: No at the moment. There are many calculi. We need do so like Newton and Leibniz did. We believe that the suggestions are not useful for our research at this time. This also implies that we have not used ChatGPT to develop "Calculus of Intelligences".

Conclusion

Artificial intelligence was over; artificial intelligences are booming around us. Artificial intelligence is significant for many people as a discipline; whereas artificial intelligences and their services have benefited people, organizations, companies, and nations. This paper explores a calculus of artificial intelligences. The main contributions of this research consist of 1). Artificial intelligences are defined as "intelligences that entities possess based on the ICT infrastructure". For example, artificial intelligences are intelligences that human beings, machines, and systems possess based on the ICT infrastructure consisting of a set of intelligent systems, technologies, and tools within various services. 2). AIE Computing = AIE science + AIE engineering + AIE technology + AIE systems + AIs + AIE services. And 3) BIs are the applications of AIs in the business domain, whereas AIs are the generalization of BIs.

Developing "Calculus of Intelligences" is not only our research but many scholars have been trying to do so, if they study calculus, logic calculus, probability calculus, and relational calculus. They are also trying to use ChatGPT and DeepSeek to explore how to develop Calculus of Intelligences. As an example, we use ChatGPT to answer questions on "how can we develop Calculus of Intelligences?" The recommendation implies that we must

cooperate with AI, including ChatGPT and DeepSeek, to explore many new topics.

In future work, we will delve into the further answers of ChatGPT to provide optimized answers to Calculus of Intelligences.

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