

Construction, Development and Utilization of Digital Infrastructure - Reference Article

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This article will explore “construction, development and utilization of digital infrastructure” as the sub-topic of “the theory of advancing the building of a community with a shared future in cyberspace to a new stage”. This article was developed based on Asia Internet History, Fourth Decade (2010s). In this article, cyberspace and digital space are used interchangeably. Similarly, we use the words digital infrastructure and cyber infrastructure interchangeably.

The digital space has two subspaces;

- Digital economy, and
- Digital society.

They are, in turn, have several aspects;

- Internet (Internet is also in the infrastructure layers)
- Artificial intelligence
- Cybersecurity
- Social media
- Internet of Things (IoT)
- Data

These aspects relied on the following infrastructure layers;

- Internet
- Telecommunications
- Optical fiber and other cables, Satellites, WiFi and other wireless communications

1. Digital Space

1.1 Introduction

The Internet turned fifty-five years old in 2024, with more than two-thirds of the global population as its users [Internet 2024]. There are various application systems based on digital technologies with the Internet and other networks as their infrastructure. We refer to these application systems as aspects of digital space. The aspects include artificial intelligence, data, social media, cybersecurity, and Internet of things (IoT) among others. Digital space and cyberspace have drawn a great deal of attention in this century, with various conferences and organizations devoted to them [Cyber 2013; Seoul 2013; ECIR 2013; Black 2010; Cyberspace 2013; Chon 2013b]. This section explores digital space, and its subspaces; digital economy and

digital society as well as aspects of the digital space. We will then explore governance of digital space and its aspects in the next chapter.

In this chapter and the next chapter, we use “cyberspace” and “digital space” interchangeably except for cases where it is necessary to separate them. Wikipedia defines cyberspace as “a concept describing a widespread, interconnected digital technology” [Cyberspace 2020]. This definition could also be used for digital space. Other similar terms such as digital world, cyber world, virtual space, and virtual world can be considered as well. Cyberspace has been discussed since the mid-1990s when the word was coined by several people including William Gibson. The word cyberspace was given prominence in his book, *Neuromancer* [Gibson 1984]. “Digital” was elaborated by many people including Nicholas Negroponte. He wrote the book, *Being Digital* in 1995 [Negroponte 1995]. Digital space is a more neutral term than cyberspace. Digital space is more harmonized with digital economy and digital society than cyberspace, too. Cyberspace tends to imply cybersecurity and cyber warfare, especially in the USA and Europe. In 2010, the US White House issued a report entitled “International Strategy for Cyberspace” [White House 2012]. The US government designated a ‘Cyber Command’ as the fifth domain after land, sea, air, and space. The European Union as well as the UK government followed suit by forming similar organizations. These initiatives brought worldwide attention to the ideas of cyberspace as well as cyber warfare.

1.2 Digital Space, Real Space, and Mixed Space

Digital space is a virtual space that is typically based on the Internet whereas real space is based on the physical world we live in. Additionally, there is mixed space consisting of both digital space and real space.[Asia 2024]

Some mixed spaces are also called cyber-physical systems, such as a sensor-based network system where the Internet and other networks are used [Cyber-Physical 2020]. Many Internet-based systems tend to be mixed spaces rather than pure digital spaces without any real space component.

Digital Space and the Internet

Digital space, when referring to digital society and digital economy, has the Internet as its infrastructure in most cases. But some digital spaces have other network infrastructures – for example, a telephone system without the Internet, a television system without the Internet, or a sensor-based network system [Claffy 2013]. Digital space has various aspects including cybersecurity, artificial intelligence, data, social media and Internet of things (IoT) among others. See Figure 2 for a diagrammatic representation of digital space, its subspaces, its aspects, and infrastructure.

1.3 Subspaces of Digital Space; Digital Economy and Digital Society

David Clark, in his paper “Three Views of Cyberspace”, emphasized three facets [Clark 2011]:

- Cyber Security
- Cyber Economics
- Cyber Society

Anthony Giddens, in his paper “Four Dimensions of Globalization”, proposed four dimensions of globalization to which Gabriela Tejada added culture as the fifth dimension [Tejada 2007, Giddens 1991]:

- World Capitalist Economy
- Nation-State System
- World Military Order
- (International) Division of Labor
- Culture

Kilnam Chon proposed the following major aspects in his paper [Chon 2013]:

- CyberSociety
- CyberSecurity
- CyberEconomy
- CyberNation-State
- CyberEnvironment

Digital Society

Digital society, including digital culture and digital life, is closest in meaning to ‘the Internet’ as they cover a similar semantic domain. With this understanding, digital society governance would be similar to Internet governance [IGF 2020]. Both digital society governance and Internet governance cover multiple social issues such as privacy, security, abuse, addiction, and violence, among others. The concepts of digital society and digital culture cover a range of contents, but the term ‘the Internet’ tends to cover this same range in a more partial fashion. The Web Index by

the Web Foundation covers various aspects of digital society as well as digital economy, as many indexes on digital space tend to consider only the digital economy [Web 2012].

Digital Economy

Digital economy is one of two subspaces of the digital space that has been developed extensively in this century. UNCTAD's Digital Economy Report 2019 stated:

“In 2016, the Digital Economy represented \$11.5 trillion, or 15.5 percent of global GDP – 18.4 percent of GDP in developed economies and 10 per cent in developing economies, on average. It found that the digital economy had grown two and a half times faster than global GDP over the previous 15 years, almost doubling in size since 2000.”

There are other indexes on the digital economy including Internet Matters by McKinsey, and the Network Readiness Index by the World Economic Forum [UNCTAD 2019; McKinsey 2012; World 2019; Boston 2011].

1.4 Aspects of Digital Space

There are the following six aspects of digital space which are covered in this chapter;

Artificial Intelligence (AI)

Data

Internet of Things (IoT)

Cybersecurity

Social Media

These aspects were covered at Asia Pacific School on Internet Governance (APSIG) in its annual schools in 2010s [APSIG 2020]. Governances of these aspects were also covered in the APSIG annual schools in 2010s.

In this chapter, we will cover these six aspects. We would like to see a “complete” set of the aspects sometime in future.

Artificial Intelligence (AI)

Artificial intelligence (AI) with the Internet and other technologies had the major development in this century [Lee 2018; Chon 2018b; McKinsey 2018; PwC 2017; Stanford 2015; Russell 2019]. Most of the current AI development is closely coupled with the Internet along with data and high-performance computing which is typically based on cloud computing as well as AI algorithms. Kai-Fu Lee calls this development the first wave of AI, which is taking place in the first decades of the twentieth century.

Almost all major companies working on AI are also the major Internet companies. They include Amazon, Apple, Facebook, Google and Microsoft in the USA, and Alibaba, Tencent, and Baidu in China among others. We expect the close symbiotic relationship between AI and the Internet to

be kept for a long time to come.

Consulting companies such as McKinsey and PwC forecasted AI's contribution to the global economy at around \$15 to 20 trillion in 2030 [McKinsey 2018; PwC 2017]. This is roughly 15- 20% of the global economy. AI is expected to impact almost every aspect of the economy and society in the coming years. AI governance is an important issue for the digital society, too, and will be described in the next chapter along with governance of other aspects.

Data

Data, in particular big data, also has a symbiotic relationship with the Internet. We had one zettabyte in the world in 2009. The growth of data in the digital space was 33 zettabytes in 2018 and is expected to be 175 zettabytes in 2025 with an exponential growth curve in the foreseeable future [IDC 2018]. The big data is also a necessary component of AI growth. Handling of these data raises many issues including privacy, ownership of the data, and abuse of the data among others. Data governance in the next chapter explores on these issues including General Data Protection Regulation (GDPR), which was developed in the EU recently [Park 2018; EU 2016; AccessNow 2020].

Internet of Things (IoT)

Internet of Things (IoT) is developed to serve devices rather than people through the Internet. IoT development started in the last century, and grew substantially in this century and surpassed the human users in this decade [Chon 2017; Gartner 2017; Kondepudi 2015]. We expect the number of devices to be connected to the Internet to grow from around 10 billion in 2015 to 100 billion or more in the next decade. We also had Mirai, the first case of malware through IoT in 2016. IoT governance including IoT security and standardization are important issues now [IETF 2019; Kondepudi 2015].

Cybersecurity

Cybersecurity has been one of the most visible aspects of digital space in this decade, partly due to the addition in 2011 of the cyber domain to the four previously recognized domains – land, sea, air, and space – in the military conceptualization by the USA, EU, and UK governments. Specifically, the organizations charged with preparing for cybersecurity and cyber warfare are as follows:

USA: Cyber Command

EU: European Network and Information Security Agency

UK: Government Communications Headquarters

Many conferences on cybersecurity were held in the twenty-first century. Some worthy of mention include the following:

Black Hat Conference

International Conference on Cyberspace

Cyber Dialogue

DEF CON

ECIR Workshop

Global Cyberspace Cooperation Summit USENIX Security Symposium

The Stuxnet incident in 2011 as well as the cyber attack in Estonia changed the cybersecurity landscape by bringing the concepts of cyber warfare and cyber weaponry into currency [Sanger 2012; Clarke 2010].

Cooperation on cybersecurity incident responses have been coordinated nationally, regionally and globally with establishment of organizations after the first worm, called Morris Worm in 1988 [Morris 2020]. The cooperation started with Computer Emergency Response Team Coordination Center (CERT/CC) in 1988 and Forum of Incident Response and Security Team (FIRST) in 1990 [CERT 2020; FIRST 2020]. Please refer Chapter 5 Cybersecurity of Asia Internet History, Third Decade (2000s) on these organizations. Please also refer APSIG on its classes on cybersecurity and cybersecurity governance [APSIG 2020].

Social Media

Social media is another important aspect in this century. Please refer Chapter 3 Social Media of Asia Internet History, Third Decade (2000s) for detail description. People tend to access social media for interacting in the digital space rather than the traditional Internet applications. Notable social networking service websites include Facebook, Twitter, Instagram, Weibo, and LinkedIn. Messaging services are also very popular, and they include WhatsApp, Facebook Message, WeChat, Line, and Kakao Talk. Social media is replacing the traditional Internet applications, particularly in East Asia where the messaging service and e-commerce as well as video are dominant applications now. Please also refer Section 3.5 Social Media Governance of Asia Internet History, Fourth Decade (2010s) for additional information.

1.5 Global Standards

Global standards for digital space are handled by various organizations with the close collaboration of national, regional and global standards bodies, which include the following:

Institute of Electrical and Electronics Engineers (IEEE)

IEEE is a technical professional organization for advancement of technology. IEEE Standard Association works on industry standards through 802 Committee and the related registration authority on MAC address.

Internet Engineering Task Force (IETF)

IETF is the standards body for Internet protocols, and it was founded in 1986, taking over the work of the Network Working Group of the ARPANET Project which begun in 1969. This includes Request for Comments (RFC), the Internet standard documents.

International Organization for Standardization (ISO)

ISO handles variety of standards including information processing. Many of them are relevant to Digital Space.

International Telecommunication Union (ITU)

ITU handles standardization and allocation on telecommunication including spectrum allocation [Restrepo 2019].

World Wide Web Consortium (W3C)

W3C is the standards body for WWW-related technologies such as HTML and HTTP.

The 3rd Generation Partnership Project (3GPP)

The 3GPP is a collaboration among the telecommunications associations of the USA, Europe, East Asia (China, Japan and South Korea) to develop standards for the third-generation mobile phone system and next generation mobile phone systems.

1.6 Governance of Digital Space and Its Aspects

The Working Group on Internet Governance (WGIG) of the United Nations defined Internet governance as follows [WGIG 2005];

"Internet governance is the development and application by governments, the private sector and civil society, in their respective roles, of shared principles, norms, rules, decision-making procedures, and programmes that shape the evolution and use of the Internet."

The Internet governance principles was revised at NETmundial Meeting in 2014 [NETmundial 2014].

For digital space, we may look into broadening the concept of the governance now. Many aspects of digital space are in their early stages, and their governances may be substantially different from the Internet governance. The concept of the governance in the Internet governance may not work well in some aspects as we are discovering in cybersecurity governance and artificial intelligence governance. The ECIR workshop on "Who controls cyberspace?" is of great interest since we still do not know how digital space will be governed [ECIR 2012].

Some aspects of the digital space governance may be appropriate to consider now. On the other hand, cybersecurity governance may be premature, which is somewhat similar to the state of nuclear technology governance in the 1950s [Nye 2011]. We may eventually need cybersecurity governance in a similar way to nuclear technology governance, which requires treaties and inspection protocols.

The IGF Workshop on "Cyberspace Governance – Exploration," was held in 2013 to discuss digital governance [Chon 2013b]. Asia Pacific School on Internet Governance offered classes on governances of various aspects in 2016-2019 including Data Governance, IoT Governance, Cybesecurity Governance, AI Governance, and Social Media Governance [APSIG 2020].

Artificial Intelligence Governance

Artificial intelligence governance has finally attracted much attention globally with various conferences and meetings, and various publications [Chon 2019; Russell 2019; FLI 2017]. AI governance may be substantially different from Internet governance in many ways. First of all, we are unable to develop any consensus on the AI principles to start with, and we have many

versions of the AI principles at present. We may also need regulations by governments since human safety is at stake such as autonomous driving. AI was included in the existential risk list issued at Cambridge University and others [Cambridge 2020; BERI 2020]. Industry is playing a major role in AI governance in this century, too.

Data Governance

Data governance is closely related to AI governance as well as privacy governance [Park 2017]. The European Union (EU) came up with General Data Regulation Policy (GDPR) in 2016, which was accepted by many countries and regions in addition to Europe [EU 2016]. We expect GDPR to take a lead on the data governance development in the coming years [AccessNow 2020].

IoT Governance

IoT governance may be developed similarly to the Internet governance, and we may consider the IoT governance as an extension of the Internet governance [Chon 2017]. The differences in these two governances may include standardization and users. The IoT standards are mostly developed by industry consortia rather than global non-profit organizations such as IETF [Kondepudi 2015]. The number of “users” in IoT exceeded human users of the Internet in this decade already, and we expect to have more than 100 billion devices connected to the Internet in the coming decades.

Cybersecurity Governance

Cybersecurity governance has been addressed actively in this decade [Tikk 2018; Chon 2016; Komiyama 2019; Cyberspace 2011]. There was much effort on developing the global norms on cybersecurity through UN and other organizations. 2015 UN GGE Report endorsed the Cyber Norms of Behavior in Peace Time as follows [UN 2015];

- *states should not knowingly allow their territory to be used for internationally wrongful acts using ICTs;*
- *states should not conduct or knowingly support ICT activity that intentionally damages critical infrastructure;*
- *states should not conduct or knowingly support activity to harm the information systems of another state’s emergency response teams (CERT/CSIRTs) and should not use their own teams for malicious international activity.*

But a consensus among state governments has not been developed. It may take much effort and time before we could come up with a good cybersecurity governance model for the world. Meantime, there is reasonably good governance on the operational level through national and regional computer security incident response teams (CSIRT) with the global organization called Forum of Incident Response and Security Team (FIRST) [CERT 2020; FIRST 2020].

Social Media Governance

Social media governance is attracting much attention lately [Park 2019; Park 2020]. We are having many important issues on the social media governance including misinformation, abuse,

and ownership on social media data among others. The social media governance is becoming closely related to the AI governance now as AI technologies are applied to the social media now. This makes the social media governance much more complex.

Other Governances

Governance of other aspects such as privacy and other human rights issues as well as social issues such as education and work may need to be addressed. The governances on these aspects may take much different formats than the governance of other aspects, and they would be the major challenges in the coming years and decades.

1.7 Issues

Global forums on governance of digital space

A few global forums currently exist that deal with digital space, including the following:

RightsCon

Internet Governance Forum (IGF)

RightsCon covers almost all areas of digital space with its over twenty program categories [RightsCon 2019]. Internet Governance Forum also covers many areas with four tracks; data, environment, inclusion and trust in its 2020 meeting [IGF 2020]. The global forums on digital space are still in their infancy as many of them were founded recently or their coverages have been expanded to cover digital space. We need to look into what we need in this area globally, regionally, and nationally.

Globalization vs Fragmentation

The digital space is being globalized including aspects and subspaces as well as its infrastructure; the Internet and the telecommunication networks. We may be facing fragmentation of the digital space including the Internet in the coming decades [Drake 2016; Mueller 2017].

1.8 Concluding Remarks

The digital space, including its various aspects, is still in its early conceptual stages, as explained in this section. We examined definitions of digital space along its subspace: the digital society and the digital economy. Then, we explored five aspects of the digital space. We would like to see further studies on the digital space, its subspaces, and its aspects as well as their governances in the coming years.

The digital space is being developed at a rapid pace in this century. AI, data, and IoT are playing major roles in the development of the digital space now. All of the trillion-dollar companies are from the digital space now. These trends would continue in the coming decades. The current coronavirus-19 (COVID-19) crisis is also contributing to the development of the digital space.

This article was development from the An Asia Internet History, Fourth Decade (2010s). [Asia

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Appendix Artificial Intelligence

Introduction

This section summarizes development of Artificial Intelligence (AI) since its inception in the mid-twentieth century to the present. AI may be classified as narrow AI and general AI [Artificial 2020; Tegmark 2017; Russell 2019; Helsinki 2018]. Narrow AI focuses on a specific task such as a game like Go and chess, language translation and so on. General AI, which we also call Artificial General Intelligence (AGI), can handle any intellectual task like a human. General AI focuses on human-level intelligence and super intelligence. In this article, we use the phrase general AI to keep symmetry to narrow AI. Most AI developments focus on narrow AI now. We may call narrow AI as AI lately.

This section covers overviews of the following topics;

- AI History
- AI Economy
- AI Applications

Super Intelligence
Complex Systems
Governance
Conferences

AI History

In the 1940s, there were several important initial developments in information technologies including a bit, digital computers, a hyperlink models, and a neural network model as well as cybernetics. Shannon defined the concept of the “bit” with 0 and 1 [Shannon 1948; IEC 2008]. Digital computers were developed in Germany, the UK, and the USA in the 1940s [Wikipedia 2019]. Bush proposed the concept of the hyperlink in his essay on Memex [Bush 1945]. However, its realization took 50 years until Tim-Berners Lee developed the World-Wide Web in 1990. A neural network model was developed by McCulloch and Pitts [McCulloch 1943]. Alan Turin wrote an article on intelligence and created the Turing Test [Turing 1950]. Norbert Wiener created the concept of cybernetics, which analyzed minds and machines [Wiener 1948].

The Dartmouth AI Workshop was held in 1956 where the term, “Artificial Intelligence” was used for the first time officially [Dartmouth 2020; Russell 2019].

With the availability of digital computers in the 1950s, the initial AI boom took place in the 1960s. However, AI researchers eventually encountered difficulty to realize AI applications, and the first AI winter came in the 1970s, as the initial optimistic views on AI disappeared. With the developments of neural networks and expert systems, the second AI boom appeared in the 1980s. Many AI researchers in Asia did not participate during the initial AI boom in the 1960s but participated from the second AI boom in the 1980s. Then, a second AI winter occurred in the late 1980s and early 1990s. The second AI winter was particularly damaging to the AI community, and many left AI activities. However, some AI researchers, including Geoffrey Hinton and his group, kept working on the AI research, in particular on the neural network, and came up with the deep neural network model [ACM 2019]. The neural network and related research led to the third AI boom in the 2010s. This was backed up with the availability of big data by Internet AI companies and high-performance computing based on cloud computing as well as various algorithms based on the deep neural network and other AI technologies.

AI Economy

PwC and McKinsey forecast the value addition by AI to the global economy in 2030 would be between 10 and 20 trillion dollars [PwC 2019; McKinsey 2018]. This amounts to 10-20% of the global economy. This gain tends to be taken by a few leading countries and a few leading companies since the nature of gain by the AI and other digital technologies are “winner takes all”. Thus, we will have an issue: How should the economic gain of trillion dollars made by AI be distributed?

AI Applications

Kai-Fu Lee in his 2018 book, *AI Superpowers: China, Silicon Valley, and the New World Order*, categorizes AI applications into four overlapping stages of waves: Internet AI, Business AI, Perception AI, and Autonomous AI [Lee 2018; Lee 2019]. Internet AI handles huge data through

the Internet. In Business AI, data are handled as parts of business processes. In Perception AI, various aspects of perceptions such as eyes, ears, and other senses are handled. In Autonomous AI, machines and systems handle sensing and respond. Their examples include autonomous robots, and autonomous driving.

Super Intelligence

Nick Bostrom published a book, *Superintelligence*, in 2014 where he proposed that developing superintelligent AI may be possible in this century” [Bostrom 2014]. He focused on general AI in his book. General AI has progressed only slightly thus far. However, Bostrom argues that it will start to take off soon, reaching human level intelligence in this century, and reaching super intelligence later in this century. Eventually, the AI will taper off later in this century or the next.

Narrow super intelligence based on the development of machine learning systems has been explored by Deep Mind Technologies among other companies and research organizations. Deep Mind developed a series of AI systems in the 2010s: AlphaGo, AlphaZero, and AlphaFold [Deep2018a; Deep 2018b; Russell 2018; Strogatz 2018; Tegmark 2017; Harari 2018].

The initial AI system was AlphaGo Fan in 2015, which was developed to compete against the European Go champion. AlphaGo Fan was based on deep learning systems, and it won a match against a high ranking professional Go player for the first time in the history. The system was upgraded to AlphaGo Lee in 2016, which represented a major breakthrough. AlphaGo Lee competed against Lee Saedol, one of the top Go players in the world, and AlphaGo won the match by 4 games to 1. It was later upgraded to AlphaGo Master in 2017, which competed against other top ranking Go players without a single loss. Deep Mind developed Alpha Zero in 2017, which plays against itself to improve its capability, and it can play several games including Go, chess, and Shogi [Deep 2018a]. It beat AlphaGo Master easily. AlphaGo surpassed human level intelligence in the game of Go, and it can be considered to have reached narrow super intelligence. In the case of AlphaZero, we may consider it is the first step beyond narrow AI toward general AI since it can cover more than one game.

Strogatz commented on potential issues with the algorithm and explainability of AlphaZero among other types of machine learning. He stated “AlphaZero gives every appearance of having discovered some important principles about chess, but it cannot share the understanding with us” in his article [Strogatz 2018]. Deep Mind also developed AlphaFold, which covers scientific discovery [Deep 2018b]. We may observe whether the Alpha Series of AI systems surpasses narrow AI and leads to general AI.

Complex Systems and Narrow AI

There are many complex systems such as the Internet, electric grids, and nuclear plants that are increasingly being handled by AI due to their complexity. These complex systems include large scale systems such as the Internet, or real-time system such as financial system. In many cases, we have to delegate to AI systems to handle these complex systems since humans cannot handle them properly anymore, which may lead us to classify these as special cases of super intelligence.

Internet Governance, Digital Governance and AI Governance

Internet governance has gone through several decades of development since the 1970s, and we are increasingly focusing on digital (technology) governance, which includes IoT governance, data governance, cybersecurity governance, social media governance, and AI governance among others.

One of the issues with governance is that it raises the following question: Can we apply Internet governance schemes, such as multistakeholderism and governance principles, to other digital governance? For most governance, we developed principles such as Internet Governance Principles and AI Principles as well as cybersecurity norms.

What constitutes AI governance is one of the major issues now. We may consider some of the following issues as the major issues of AI governance [Tegmark 2017; Russell 2019; AAAI 2019; Chon 2019; FLI 2017; FHI 2019];

- Principles
- Policy
- Ethics and Human Rights
- Accountability, Explainability, and (Algorithmic) Transparency
- Security
- Safety
- Social and Economic Impact
- Data

AI communities are working on the above issues. We have fairly solid results in some issues including the principles and the ethics, but most of the issues are still in their early stages of development [FLI 2017; EU 2019b; EU 2020; Dafoe 2018]

Please refer Chapter 3, “Digital Governance”, for detail descriptions of digital governance, and the governance of its aspects including artificial intelligence governance [Asia 20].

Major Conferences on AI and Machine Learning [Pal 2019]

- NeurIPS – Neural Information Processing Systems
- ICML – International Conference on Machine Learning
- ICLR – International Conference on Learning Representations
- AAAI – Association for the Advancement of Artificial Intelligence
- CVPR – Computer Vision and Pattern Recognition
- ICCV – International Conference on Computer Vision
- GECCO – Generic and Evolutionary Computation Conference
- COLT – Conference on Learning Theory
- IROS – International Conference on Intelligent Robots and Systems
- ICIP – International Conference on Image Processing

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