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Plan for Construction and Utilization of Knowledge-Service Platform for Supporting Biomimicry Technology Development

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ABSTRACT

In order to support biomimicry technology development, it is necessary to develop an omnidirectional service platform which can recommend principles of biomimicry and business ideas, providing experts' networks and carrying out their relevant education and promotion on the ground of baseline data and application research materials related to biomimicry. This study was conducted to establish any probable plans for construction and utilization of the future open-platform which will collect and serve the technology of biomimicry. Accordingly, biological and ecological information databases were examined along with the appreciation of construction and management of major biomimicry DB, and, based on the materials from the interview of related experts, a customer journey map was schematized. Lastly, in order to suggest a mid-to-long-term target-model, the roles of a future biomimicry knowledge service-platform were determined along with the potential plans for its construction and management based on case analysis and customers' needs.

Keywords: Biological and ecological database, Biomimetics, Biomimicry, Customer journey map, Knowledge-service platform, Mental model

Introduction

In the late of the 20th century when the advance of technology ran up against various limitations, an innovative progress became indispensable. Just at this time there was an advent of biomimicry technology focusing on the nature's survival principles to find out creatures' traits so that the leap of new technology might be materialized (Lurie-Luke, 2014). Out of the human-centered thinking which had simply considered the nature as the subject of curiosity or development emerged a new way of thinking for learning from the nature to figure out solutions (Lim *et al*., 2018). Biomimicry a new social technology in the future which applies any basic structure or principle of the ecosystem or of the biological resource so that any environmental or social problems could be solved (Benyus, 1997; Bhushan, 2009), includes approaches for finding out environment-friendly and sustainable solutions through the mimicry of the structures optimized by their adaptation to the environment for a long time and of the efficient strategy for using material and energy (Bae *et al*., 2019; Geol, 2013; NIE, 2020).

Since most of the biological and ecological principles

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existing in the nature have the efficiency of remarkably excellent resources, they could be the superb subjects for mimicry (Dickinson, 1999; Stone *et al*., 2014) and have a strong potential of producing the outcome which is a solution with a high sustainability (Chakrabarti, 2014). In spite of this positive expectation and experimental proof, there exist several limitations to the development of new technology which enables the utilization of the biomimicry, a representative one of which is that, compared with the total amount of the information in the nature, what researchers and engineers can utilize themselves is too little for them to explore the knowledge on the nature for themselves, which can't help limiting their capability of sorting out the characteristics of biomimicry that are applicable to any problem solving (Kim, 2018; Vincent *et al*., 2006).

Around the 2000's, the USA led research of the methods for exploring the biological and ecological information to develop the system which enables the utilization of biomimicry principles (NIE, 2020). In conducted the research for exploring the biological and ecological information for the construction of information and search system (Kim and Lee, 2017; Nagel *et al*., 2017). It is known that the system providing the most biological system information as of now is furnishing the information on 21,000 genera (Kim and Lee, 2017). Most of the attempts employed for the development of biomimicry technology, however, undergo lots of trial-and-errors before finding out any solutions qualitatively, and those tools used for technology development are too extensive to produce enough solutions. In addition, it is often inevitable that related experts be equipped with not only the knowledge of engineering technology but also the expertise on biological and ecological function, structure, behavior and production so that they may develop new technology (Vincent, 2014).

Therefore, it is necessary that various consumers such as engineers, entrepreneurs and managers as well as researchers should develop a service platform which supports a practical development of biomimicry technology. We suggest a target-model after researching case investigation and interviewing those working in various fields while looking into its expectation effectiveness in order to meet the needs of consumers in different areas and provide the plans for construction and management of a knowledge service platform which enables the support for the development of biomimicry technology.

Materials and Methods

As analysis materials were used the findings from the research of 31 DB's on biological and ecological information home and abroad, the results from the investigation of the 5 current biomimicry DB's and the outcomes from in-depth interviews of 17 experts on biomimicry conducted from October 2019 to March 2020 both face-to-face and in written form. First, the biological and ecological information DB constructed home and abroad was analyzed for the classification of basic-data types along with the categorization of the key status of biomimicry DB construction and management into 6 items for appreciation of features. Second, a customer journey map was schematized on the basis of the findings from the interview of related experts so as to examine how those consumers explore biomimicry information and apply it to technology development. Last, a target-model was suggested that enables determining the role of biomimicry knowledge service platform and establishing the plans for its construction and management.

Results

Biological and ecological information DB type and biomimicry DB cases

Biological and ecological basic data type

For biomimicry knowledge DB to support biomimicry technology in omnidirectional ways, it is necessary that biological and ecological information DB, which is fundamental, were analyzed. This study, not limiting the types of basic data to what is directly related to biomimicry domains, investigated the cases of 31 biological and ecological basic data including Zoology, Ecology, Bioinformatics, and OMICS DB, for it would be difficult to predetermine which data could be of indirect help for the extraction of biological and ecological principle afterward (Table 1). Some DBs are not allowed to be accessed and utilized publicly. In this case, references were used (Hulo *et al*., 2006; Maglott *et al*., 2011; Thorisson *et al*., 2005; Xenarios *et al*., 2000). The investigation found that most of the basic data require a certain license (only internal access permitted) while several DB delivery services like European Molecular Biology Lab are open for the public to access API (application programming interface) and download DB for the promotion of public interest.

Biological and ecological information DB's were classified into two types. First, classified according to the scale of biological and ecological information, is being used for grouping the traits of biological and ecological basic data (Table 2). It was planned to track how the basic data was being utilized not only for conceiving any ideas but also for materializing finished products. To put it concretely, it is defined as biomimomic traceability matrix (BTM), which is a model modified from STM (science traceability matrix) resulting from tracing and analyzing, from the viewpoint of information flow, each decision-making process for engineering implementation of the scientific knowledge produced from the frame of NASA's existing science projects (Martinez, 2017).

Table 1. Types of biological and ecological information DB

Data classification	Name of basic DB	Development or management agency
Meta DB	ConsensusPathDB (http://cpdb.molgen.mpg.de/)	Max Planck Institute for Molecular Genetics
	Entrez (Maglott *et al*., 2011)	National Center for Biotechnology Information
	Neuroscience Information Framework (https://neuinfo.org/)	University of California, San Diego
Model Organism DB	PomBase (https://www.pombase.org/)	University of Cambridge, University College London
Nucleic Acid DB	DNA Data Bank of Japan (https://www.ddbj.nig.ac.jp/index-e.html)	Center for Information Biology and DNA Data Bank of Japan
	EMBL (https://www.ebi.ac.uk/)	European Molecular Biology Laboratory
	GenBank (https://www.ncbi.nlm.nih.gov/genbank/)	National Center for Biotechnology Information
	23andMe (https://www.23andme.com/en-int/)	23andMe
	HapMap (Thorisson *et al*., 2005)	National Human Genome Research Institute
	OMIM (https://www.omim.org/)	Johns Hopkins University
	RefSeq (https://www.ncbi.nlm.nih.gov/refseq/)	National Center for Biotechnology Information
	1000 Genomes Project (https://www.internationalgenome.org/)	EMBL - European Bioinformatics Institute
Protein Sequence DB	Database of Interacting Proteins (Xenarios *et al*., 2000)	University of California, Los Angeles
	DisProt (https://disprot.org/)	University of Padua
	InterPro (https://www.ebi.ac.uk/interpro/)	European Bioinformatics Institute
	MobiDB (https://mobidb.bio.unipd.it/)	University of Padua
	neXtProt (https://www.nextprot.org/)	Swiss Institute of Bioinformatics
	Pfam (http://pfam.xfam.org/)	European Molecular Biology Laboratory
	PROSITE (Hulo *et al*., 2006)	Swiss Institute of Bioinformatics
Protein Structure DB	Protein Data Bank (https://www.rcsb.org/)	World Wide Protein Data Bank
	SCOP (https://scop.berkeley.edu/)	University of Cambridge
Taxonomy	Integrated Taxonomic Information System (https://www.itis.gov/)	Smithsonian Institution
	EggNOG (http://eggnog5.embl.de/#/app/home)	European Molecular Biology Laboratory
Characteristics	Map of Life (https://mol.org)	University of Cambridge
	BIOTIC (http://www.marlin.ac.uk/biotic/)	National Marine Biological Library
	TRY (https://www.try-db.org/TryWeb/Home.php)	Future Earth
	FishBase (https://www.fishbase.de/home.htm)	Sheryl Yap and Rainer Froese
Gene Expression DB	Ensembl Genomes (http://www.ensemblgenomes.org)	European Molecular Biology Laboratory
	Ensembl (https://asia.ensembl.org/index.html)	European Molecular Biology Laboratory
	Ensembl Metazoa (https://metazoa.ensembl.org/index.html)	European Molecular Biology Laboratory
	Ensembl Bacteria (https://www.re3data.org/repository/r3d100011195)	European Molecular Biology Laboratory

The other is the type of biological and ecological information DB's by industrial sector. Since the sector of biomimetic industry have different categories due to the method of its definition, the analysis was carried out on the basis of the biomimetic industrial sector defined by civil and government agencies at home and abroad (Fig.

Table 2. Biological and ecological basic DB classified by BTM

Classification	Name of basic DB
Biological Traits	Trait Information of Map of Life, BIOTIC, TRY, etc.
	Identification information of Delta Project (in Netherlands), FishBase, etc.
	Biodiversity Information of CBD, EcoBank, etc.
Organismal Complexity	Taxonomy Information of ITIS, etc.
	Phylogency Information of EggNOG, etc.
	Entrez
	Genom Information of Ensembl, Ensembl Genomes, etc. Ensembl Metazoa, Bacteria
Specific Function	Protein Information of DisProt, SCOP, Protein Data Bank
	Ecological Information of EcologicalDataWiKi, etc.
Molecular Instantiation	Nucleic Acid Information of GenBank, etc.
	Biochemistry Pathway Information of ConsensusPathDB, etc.
Technological Implementation	Dissertation Information of PubMed, JSTOR, etc.

BTM, biomimomic traceability matrix.

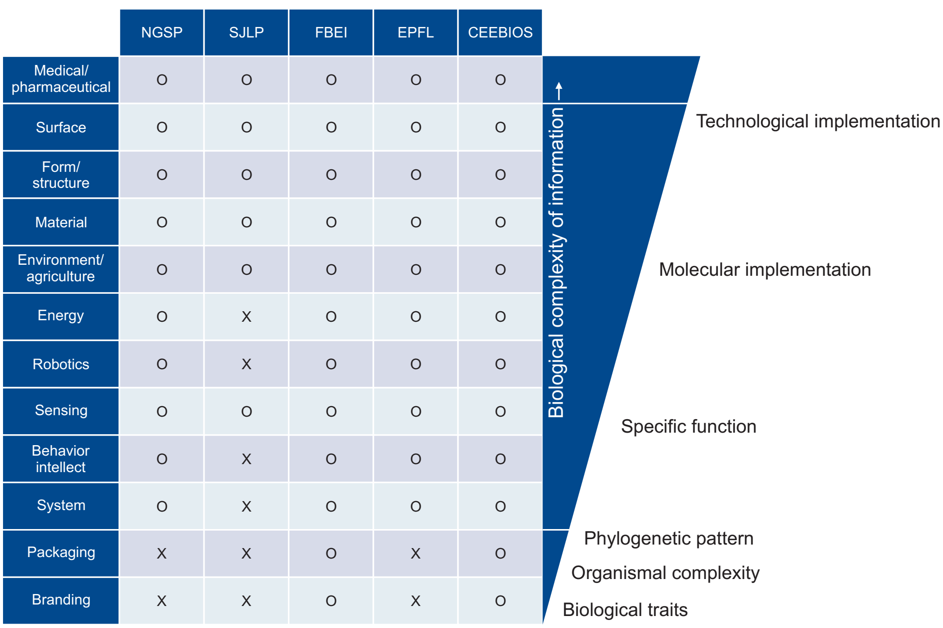

Fig. 1. Difference in recognition of biomimicry industrial sector and diversity of biological and ecological basic data group. NGSP, North Gyeongsang Provincial Government; SJLP, South Jeolla Provincial Government; FBEI, Fermanian Business and Economic Institute; EPFL, *École Polytechnique Fédérale de Lausanne*; CEEBIOS, *Centre d'études et d'expertise en biomimétisme.*

1). Though Fermanian Business and Economic Institute (FBEI) presented that there were 12 sectors which would be influenced by biomimicry technology, it was confirmed that each country or each agency recognizes the targets which are subject to the application of biomimicry technology a bit differently. When BTM is employed to examine 12 traditional industrial sectors which will be benefited from the substantiation of biomimicry technology by FBEI (2013), the area of traditional industrial sectors and those needing biological and ecological basic data can be understood because it is possible to infer what level of biological and ecological basic data have an effect on which industrial sectors.

In Korea, North Gyeongsang and South Jeolla Provincial governments defined the category of their own biomimicry technologies when writing their reports for the attraction of biomimicry cluster, which showed some differences in their recognition on the diversity of biological and ecological basic data group based on BTM and the appreciation of biomimicry technology industrial sectors. Furthermore, it was found that the biomimicry technology category recognized by those two governments is relatively narrower than those recognized by foreign agencies (FBEI & *Centre d'études et d'expertise en biomimétisme* [CEEBIOS]). Given that there is not enough consideration of those areas requiring phenotypic property information and phylogenetic information, it is obvious that there is the necessity for developing biomimicry knowledge service platform with the goal of acquiring the maximum amount of international biological and ecological basic data with the 12 above industrial sectors covered.

Cases of major biomimicry DB

After the examination of 6 items such as type and information amount of biomimicry DB, search and application function and probability of tech-development support in 5 DB's (AskNature, NatureTech, IDEA-INSPIRE, DANE, Bio-TRIZ) managed currently home and abroad, it was found that they were being managed, only in the short term, for the purpose of promoting the information on the principles of biomimicry and providing various users with interesting information (Table 3). This problem was found to be caused by the proactive and follow-up management service for the substantiation and commercialization of biomimicry technology and the intolerance of the provided biological and ecological principles. Accordingly, it was determined that future biomimicry knowledge service platform haves discrimination from biomimicry DB from the viewpoint of both short and long strategy for the purpose of service, the relevance of provided information, the support of scenario for information search and the position of service.

Customer journey map by mental model

Mental model is a behavior that users extract positive or negative elements in their existing behavior patterns consciously or unconsciously through interviews, based on which the difficulties and predicaments during their experience of substantiation and commercialization can be drawn out so that any elements needed for the substantiation and commercialization support programs may be analyzed (Jones *et al*., 2011). Particularly, in this study, the experience of substantiation process was schematized in the form of customer journey map.

It was found how experts was exploring the information and knowledge on biomimicry. The experts were asked what information they wanted and expected to input and output and what search methods they employed in the cases of concrete exploration (not only when searching online but also when exploring books, dissertations and their acquaintances around them). We found the mental model of the process of implementing biomimicry-ideas into products through a 5-step user journey map (Fig. 2).

The common features of those subjects found from the interview were that they wanted 'Additional Learning' of the knowledge on biomimicry, biology and ecology through 'Knowledge Seeking'. It is absolutely true that the technical terms used in relevant domains must have been unfamiliar to them while acquiring the information on new domains. However, they still wanted to keep learning these new terms consistently through the process of knowledge seeking. The fact was also revealed that not only they referred to the texts and the schematized images explaining any relevant terms or methods, but they asked their acquaintances (fellow-researchers or relevant experts) very frequently during the learning process as well. On the other hand, they showed a pretty picky tendency when selecting the objects of information exploration for the satisfying reliability on the newly acquired information. The methods to secure reliability on media are seen to vary depending on the experience of each researcher, which is the reliance on the media's reputation, or on their acquaintance's expertise, or on the paper citation counts and article clipping number or the backward search of the context related to their own professional field among already published contents in media.

It was interesting that a great many of the interviewees had their own bias toward biomimicry. Especially those experts who had dedicated to a certain research field were found to have the firmest conviction for methodology and knowledge-seeking method used widely in their professional field while heavily relying on them. Interviewees were heavily dependent on the biological and ecological information intuitively coming to their mind to keep searching for information by using familiar methods of knowledge-seeking with any relevant keywords rather than opening their mind to completely new possibilities for searching the information or exercising their own ideas.

Through the insight from these interviews was obtained the functional requirement that there is a specific need to permit each of those experts individually specialized knowledge-seeking. Furthermore, it was determined that first of all it should be proposed as a prior task to build reliability between experts and knowledge DB with the application of the method providing the information with close relevance if any information so widely known as to be stale has the same context and content as those of what any experts try to explore.

It was summarized that there are 3 key functional requirements: (1) Function of free knowledge seeking, (2) Function of summarizing knowledge, and (3) Function of information verification. In particular, it was confirmed that the network among experts could be supported and at the same time an online-cooperation system support is indispensable for making it possible for them to collect knowledge-seeking patterns generated during networking.

Target model for biomimicry knowledge service platform

It was found that, for an efficient utilization of biomimicry knowledge service platform with all the above facts, the target model should be established by the phase of short, medium and long terms and the supporting strategy suitable for each phase is needed (Fig. 3). Ultimately all phases for substantiation of biomimicry technology should be backed up and the establishment of

Table 3. Major biomimicry DB

DB name	Institution	Level of knowledge basis	Degree of DB sustainability	Service accessibility	Expandability of connectivity to other areas	Price competitiveness	Business model
AskNature[1)]	Biomimicry Institute	+ Arrangement of paper abstract	+ Curator handwork	++++ Access to online	+ DB of blog type	++ Cost for visiting training	Consulting & training of biomimetic expert
Nature Tech[2)]	Tohoku University	++ SEM image included	+ Researcher handwork	++++ Access to online	+ Limitation to biomimicry	++++ Free	Online platform
IDEA-INSPIRE[3)]	ILSc	++ Knowledge on physics included	+ DB for test	-	-	-	Online platform
DANE[4)]	GATECH (USA)	+ Limitation to functional vocabulary	+ DB for test	++++ Access to online	-	-	Online platform & education of biomimetic in middle and high school
BioTRIZ[5)]	BioTRIZ (Univ. of Bath) (Britain)	++ Knowledge on physics included	+ DB for test	+ Visiting consulting	++++ Interdisciplinary consultant	+ Large-sum consulting cost	Online platform & consulting

SEM, scanning electron microscope.
1) https://asknature.org/ (access date: 2021.6.10.)
2) https://www.nature.com/collections/fxvqrpnlcq (access date: 2021.6.15.)
3) https://cpdm.iisc.ac.in/cpdm/ideaslab/ideainspire.php (access date: 2021.6.15.)
4) http://dilab.cc.gatech.edu/dane/ (access date: 2021.6.20.)
5) https://biotriz.com/ (access date: 2021.6.10.)

I. Before project execution	II. Pretest			
Conduct research and projects in specific fields	- Search company related to research - Search for papers - Search news	- Examine product improvement point and characteristics - Investigate company patent - Examine the products available for research and application - Search commercial products - Search company's core technology	Look for any user interview relevant to the research and marketing report	- Search news and technology patent - Check the business direction of leading enterprises - Investigate the patent of leading enterprises
Research of specific (professional) fields and project progress	Check preceding research	Examine existing products	Investigate market data	Appreciate the technology trend
Research networking	- News portal - Dissertation and patent search site - Enterprise information search portal	- Stock, enterprise and market situation portal - Product purchase site	- Trend reporting site - Market research site	- News portal - Patent search site

III. Research progress				IV. Verification				V. Finishing
- Seek for advice from acquaintances - Contact dissertation author	- Search engineers and biological researcher - Send E-mails to acquaintances - Make phone-calls to acquaintances	Search biological DB	Datafication of design features of specific creatures	- Utillize simulation rules - Ask external agencies for evaluation	- Listen to feedback of experts in relevant field - Listen to feedback of project co-workers - Listen to feedback of professors	Evaluate product properties	Check one's verifying method	- Obtain storytelling ideas by news search - Search news for currently impacting subjects
Obtain additional information or insight	Look for who will research together	Look for data of the field to be grafted	Analysis of design features	Execute protype test	Listen to feedback	Performance testing	Look for analogous study	Write reports
Institute introduction site	Researcher search site	Biological DB portal		Evaluate agency inquiry site	Similar industry expert search site	Evaluation agency inquiry site		

Fig. 2. Customer journey map by mental model utilizing biomimicry knowledge.

5-phased strategy for biomimicry knowledge search/incubation and education-substantiation-spread and sharing is indispensable.

Biomimicry knowledge service platform of a short-term conception provides the function of searching biomimic ideas based on key social issues, restrictively supports researchers' network for the resolution of any present issue of substantiation and promotes the examples of innovative commercialization. The biomimicry knowledge service platform with a mid-and-long term concept will be driven as a complete platform, constructed and managed with the goal of realizing the service which have a satisfying support for the inference and substantiation of the biomimicry information foothold as a functional requirement mentioned above. For this, the functions of information search and application and of support for the solution to any designing process problem and commercialization could be implemented.

Discussion

Those existing biological and ecological information DB and biomimicry DB was materialized only the simple function for information search. Unlike any common information search, the knowledge-seeking for the development of biomimicry technology is able to extract creative ideas from the fragments of similar knowledge. Therefore, the biomimicry knowledge service platform should realize the pre-and-post management service for the biomimicry ideas which can support the development of biomimicry technology.

The ultimate expectation effects of biomimicry knowledge service platform are the followings: (1) Consumers of biomimicry can search any technical idea very easily and fast, (2) The innovation of biomimicry which has been impracticable due to a knowledge barrier becomes possible, (3) The industrialization of indigenous species

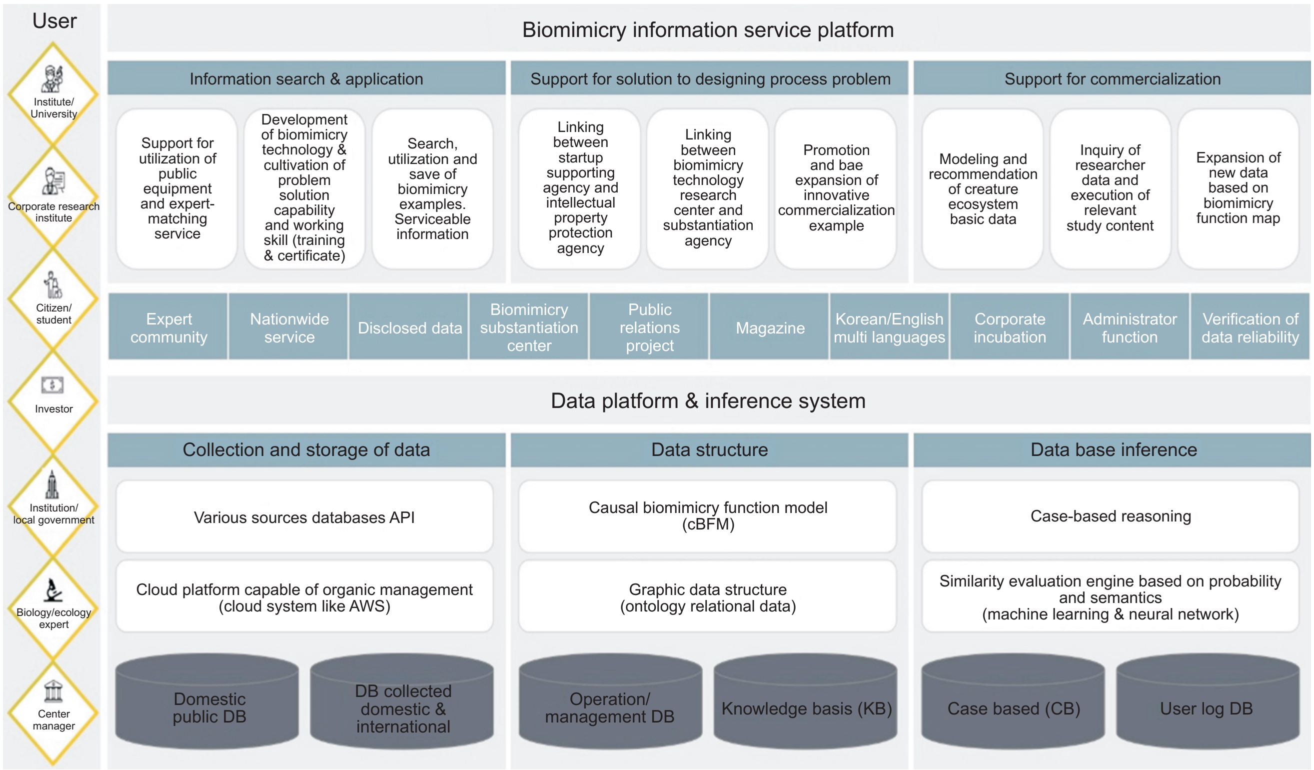

Fig. 3. Mid-to-long term target model of biomimicry knowledge service platform. API, application programming interface; AWS, Amazon Web Services.

in Nagoya Protocol can be accelerated, (4) The decision of technical standards in every industrial field interested in the industrialization of biomimicry technology will become possible, which will be helpful to guiding the development of international standards and leading technology, and finally (5) The biomimicry knowledge service platform will result in the creation of new markets and new industries and then the creation of new jobs.

Conflict of Interest

The authors declare that they have no competing interests.

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