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"Oil is the New Data": Energy Technology Innovation in Digital Oil Fields

HaeOk Choi and Hwanll Park *

Science and Technology Policy Institute, Sejong National Research Complex 370, Sicheng-daero, Sejong 30147, Korea; hochoi@stepi.re.kr
* Correspondence: hipark@stepi.re.kr; Tel.: +82-44-287-2461

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Abstract: Digital oil fields (DOFs) are built on data produced from energy technology innovation during the application of new technologies to oil resource development. In this study, this conversion is examined through the paradigm switch to "oil is the new data". An analysis of related patents shows that DOF technology is developing through convergence and close links with other industries, specifically the equipment, parts, and material industries. Additionally, it is conjectured that the strategic preemption of standards will emerge as an important policy issue because a standard must be established for the interoperability of the elemental technologies of DOFs. Furthermore, with the expansion of DOF-related technologies, device-related technologies have also been developed. Of these device-related technologies, sensor technology specifically provides new possibilities for the development of DOFs. The significance of this study is that it explains the evolution of DOFs over the course of 10 years, which is illustrative of technological innovation in the field of energy-related development and data collection.

Keywords: digital oil field; oil upstream; technology innovation; oil exploration and production; energy policy

1. Introduction

The expression, "data is the new oil" implies the considerable current economic value of big data in the digital era [1]. This indicates that data, like coal and oil used as raw material and fuels for industrial applications, may be used to develop other industries, creating new economic value. Recently, the oil exploration and production (oil E&P) industry has been generating, storing, and using vast amounts of data. The oil E&P industry has applied sensors throughout the entire oil production process to create data in real time, and uses artificial intelligence to analyze the collected data to make decisions efficiently. We describe the digital transformation of the oil E&P industry as the digital oil field (DOF). DOFs, which are preoccupied with value added data, have attracted significant attention recently with the introduction of new technologies. Since DOFs are oil fields that produce big data, we paraphrase the term "data is oil", to state that "oil is the new data". Furthermore, data have garnered attention as the crude oil of the 21st century [2]. To date, data have had a great impact worldwide, such that new economic drivers have been established owing to its applications throughout industry. Although the resource development industry has been dealing with vast amounts of material for a long time, the rapid development of computers, sensors, information and communication technologies (ICTs) in recent years has exponentially increased the amount of data being generated. Big data technologies can be used to analyze large amounts of unstructured data that hitherto could not be processed. As processing technologies, big data analysis methods are the basis for realizing intelligent services [3].

Recently, big data analysis has been utilized for innovation based on new DOF technology. DOF innovation is progressing rapidly because the combination of resource development and ICT can reduce the overall cost and increase profitability of the whole process. To develop a DOF, it is necessary to study the optimal search path by combining various data such as geographic information, field information, core data, and reservoir data. Therefore, related patents, which are being continuously monitored, have been filed in connection with these fields [4,5]. DOF technology primarily develops by adopting technologies from fields such as short-range and telecommunication infrastructure, cloud computing and integrated data management, digital sensor modules, and data analysis and visualization [6]. This is different from existing energy-related data conversion, which necessitates the periodic consideration of technology for comprehensive data collection. This study contributes toward finding ways to develop energy-related innovation capabilities through the analysis of DOF-related innovation capabilities.

Although the influence of oil in some areas in the world is diminishing due to the increasing deployment of renewable energy, oil remains important in the world economy. Recently, with production rates in traditional oil and gas fields reaching their peaks, or even depletion stages, exploration environments have become increasingly hostile owing to greater target depths, more extreme climates, or inaccessible locations. In the case of new petroleum resources such as shale gas, the required drilling per unit of leased area is typically higher than that of conventional petroleum resources, and so are the required work and management operations, such as in hydraulic crushing. DOF technology makes it possible to efficiently manage sites that require oil wells comprising several hundred to several thousand holes, such as those for shale gas, and to facilitate the unmanned or remote management of oil and gas development sites in extreme or remote locations. In addition, data generated in the oil production process are being leveraged to increase production and economic efficiency through risk prevention and demand forecasting. Therefore, this study aims to identify the implications of DOFs in the field of oil resource development using specific data. Various efforts have been made in the DOF-related hardware field to remotely monitor and control oil wells [7] by integrating ICT technologies such as data communication with servers and real time data processing. Research in this field is ongoing [8,9].

Several technological innovations have been designed recently in the field of oil exploration and production, through the adoption of new technologies [4]. DOFs are convergence technologies that manage and operate online [10,11]. New technologies that are adopted in the field include the extraction of limited petroleum resources. Examples of the extraction technology include extreme pole and gas hydrates, recovery/production by robots, AI-based exploration and evaluation technology, digital production optimization technology (DOF), and consumption prediction using big data [3,12]. This research reflects these new technologies based on data accumulated in the oil resource development field [13,14]. DOFs, in relation to petroleum resource development, have the potential to facilitate the creation of various business models through their roles as platforms for scaling and managing data. Dominant technology development companies in the petroleum field have a strong network in the value chain process, which makes it difficult for new startups to participate in this area. This is a real problem, as it is difficult for new companies to penetrate a niche market with well-established methods and strategies. As an opportunity for new companies to participate in the digital oil field, we make this field our focus. We believe that the results of this study can be used as reference material for future oil-related policies.

In this study, the structural characteristics of the innovation process in DOFs were investigated through the conversion of energy-related innovation capabilities focused on oil resource development stages. To this end, we analyzed changes in the innovation capabilities and structural characteristics of DOFs, which focus on using data to produce value addition. Previous studies on the digital oil field have focused on detailed element technology or business feasibility for specific cases [10,15–18], without discussions about the overall system perspective. In addition, there is little research that analyzes the contents of unstructured data using actual patent data in detailed technology. Furthermore, compared with the interest in the rapidly developing digital oil field owing to the grafting of new technologies, limited research has been conducted on case studies, and research on the structural characteristics related to technological innovations in this field is insufficient [10,17,19].

This study aims to solve major issues in technological innovation processes taking place in the digital oil field by using data on actual patent content. Specifically, by analyzing the innovation capabilities of DOFs, future research directions will be derived and proposed. The characteristics of the rapidly growing innovation capabilities of DOFs will be examined, and conclusions will be drawn. To overcome the limitations of existing research methods, we focused on innovative competency-related data (unstructured data in patents), and analyzed and derived structural implications through the analysis of structural characteristics over time.

2. Materials and Methods

The main activities of oil E&P are composed of exploration, reservoir characterization, development, and production, which collectively have the highest number of patents. We analyzed how DOF technologies evolved in the above mentioned areas. First, we focused on the development and production fields, which have the highest number of patents for E&P activities. We analyzed these patents using DOF-related methods. We collected and analyzed related data and derived future implications. During the study, relevant experts on patent-related search formulas were consulted (see Appendix A).

In oil E&P, securing core technologies is directly linked to profitability at each stage of the oil and gas field development; therefore, it is necessary to identify and continuously monitor core competencies. Despite the importance of these core competencies, they have so far hardly been organized and analyzed based on the number of patent applications and trends by country. In this study, we deployed a differentiated analysis method to overcome the limitations of existing research methods and to continuously monitor innovation capabilities in the field of oil resource development. For innovation capability analysis, we attempted to extract key content using patent document information such as unstructured and text data, and identify the key content and issues using cluster analysis and topic modeling.

Topic modeling is a machine learning technique that can extract the topics inherent in document data to classify documents or derive word clusters that constitute topics. The topic analysis modeling method extracts topics through the latent Dirichlet allocation (LDA) algorithm and visualizes the clustering of keywords and documents for each topic. The rationale for using the LDA algorithm in topic modeling is to discover the hidden semantic structure of the text body. In particular, LDA extracts topics by estimating the probabilities that a word exists in a specific subject and that a specific subject exists in a document as a combination probability [20]. This study uses scientific analysis tools to understand the knowledge-based network structure of the digital oil field, monitor the technological innovation process, and utilize the results of the analysis in policy development, supporting the entry of startups into the field.

The analysis steps (shown in Figure 1) are as described here.

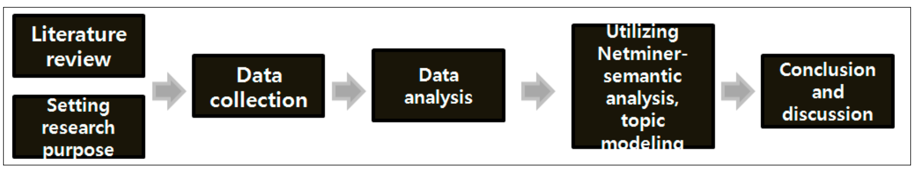


Figure 1. Research process.

First, the related literature was investigated to determine DOF research trends in the field of oil resource development.

Second, methods for collecting DOF-related data were designed in consultation with experts in the relevant fields, and a search formula for finding related patents was derived (Appendix A). Data from the last 9 years (2 June 2011~2 June 2020) were collected from the Korean Intellectual Property Office. A total of 15159 data points were collected. The Korean Intellectual Property Office database is a reliable site showing the current status of each country's patents by linking up with the patent databases of other countries.

Third, the cluster network analysis method and topic modeling technique were used to examine the structural characteristics. Through these methods, major issues and contents were analyzed to draw their implications. Unstructured patent data were used for this analysis. The patent number and applicant data were omitted, and the patent description and unstructured data related to the title were collected, analyzed, and processed.

Fourth, to analyze the yearly change in innovation capacity, each keyword was extracted by dividing the data for the 9 years into three-year ranges, such as 2011~2014, 2015~2017, and 2018~2020.

Finally, conclusions were drawn based on the analysis of the contents, and future research tasks were proposed.

This study attempts to understand the structural characteristics of network formation by first determining the knowledge-based network structure occurring in the digital oil field, and then monitoring, in detail, the changes that occurred in the last 9 years. This is meaningful in monitoring the innovation capacity of the digital oil field, which has been rapidly changing in recent years. Additionally, this study is different from other studies in that it contains an abundant, unseen knowledge-based network structure that focuses on the contents of patent data and attempts to analyze it so as to overcome the limitations of analysis methods based on patent frequency alone.

3. Results

In this study, semantic network analysis was utilized to examine the structural characteristics of the innovative capabilities of DOFs. First, by analyzing the entirety of the 9-year data, we attempted to analyze critical keywords and issues in the related topics. To examine the temporal changes in technological innovation, the data were split into three time divisions.

The following results were obtained by analyzing the structural characteristics of DOFs (Table 1). To interpret the results by group (Figure 2), an analysis was attempted by referring to a study that distinguished existing DOFs [21,22], and explained the characteristics of their related technologies at each stage. This study was used to interpret the high-ranking keywords and main contents of each group among the classification groups, with reference to existing studies (see Table A1).

The most common keywords from the first group, denoted by G1, include "method", "system", "composition", "material", and "use". This group represents the transmission role within the system in the DOF. It can be identified as the component serving as the communication infrastructure, which assembles, supports, and builds hardware-related technologies.

The second group, G2, mainly focuses on keywords such as "process", "apparatus", "control", and other terms related to process modeling in the DOF that involve interpretation and control of the collected data. The group is closely related to automation, which is important for optimizing the overall work processes. Traditional technologies in the field of oil resource development are being utilized to support the overall system efficiency improvement of DOFs by combining AI and machine learning, which are nontraditional technologies, to support decision making [23,24]. It was also confirmed that these technologies are closely related to those used in the equipment industry in terms of remote monitoring and control.

Among the main technologies in a DOF, process control can be made redundant by improving the efficiency of the oil field using methods such as prediction and production optimization through automated data collection and alarm systems. The management life cycle is divided into data processing, analysis, and modeling. Specifically, this process is used to make decisions with data obtained from petroleum resource development [25,26].

Table 1. Results on group network analysis of digital oil fields.

G1 (Communications Infrastructure)			G2 (Processing Modeling)			G3 (Sensor and Interface Support)			G4 (Control Hardware)		
Keywords	**Frequency**	**Degree Centrality**	**Keywords**	**Frequency**	**Degree Centrality**	**Keywords**	**Frequency**	**Degree Centrality**	**Keywords**	**Frequency**	**Degree Centrality**
method	4669	93	process	1046	59	device	718	39	plant	164	26
system	1972	73	apparatus	760	41	treatment	396	52	power	139	19
composition	1196	62	oil	750	49	production	392	56	acid	121	20
material	688	51	sand	655	57	fuel	204	25	unit	76	17
use	600	65	gas	459	46	compound	174	21			
product	333	39	fluid	375	36	particle	135	17			
surface	297	40	water	371	48	agent	129	18			
coating	225	26	hydrocarbon	312	40	mixture	119	27			
preparation	201	30	control	281	37	medium	109	22			
polymer	187	33	application	201	31	storage	106	23			
metal	186	31	recovery	195	35	bed	97	18			
structure	184	26	formation	183	17	soil	91	11			
assembly	178	24	catalyst	168	18	reactor	90	15			
Tool	173	21	processing	155	27	filter	83	22			
carbon	157	23	heat	153	26	chemical	81	25			
cement	149	18	energy	144	18						
mold	140	22	waste	143	29						
component	129	25	flow	136	23						
construction	120	22	operation	128	20						
vehicle	119	19	fracturing	123	22						
sanding	113	13	conversion	115	18						
core	104	21	bitumen	107	20						
casting	101	18	stream	103	16						
manufacture	100	18	removal	101	27						
article	98	14	extraction	100	21						
manufacturing	97	20	temperature	98	19						
proppant	97	11	slurry	96	20						
formulation	96	18	separation	91	19						
element	93	8	feedstock	89	19						
layer	90	18	tailing	84	11						
machine	90	12	pressure	83	13						
resin	90	15	biomass	82	18						
panel	89	13	liquid	81	15						
glass	86	16	screen	77	11						
concrete	85	12	well	76	13						
skin	83	6	steam	75	12						
fiber	81	11	proppants	74	8						
foam	79	22	field	72	14						
binder	76	12									
support	76	12									
body	75	11									
building	72	12									
fracture	72	12									

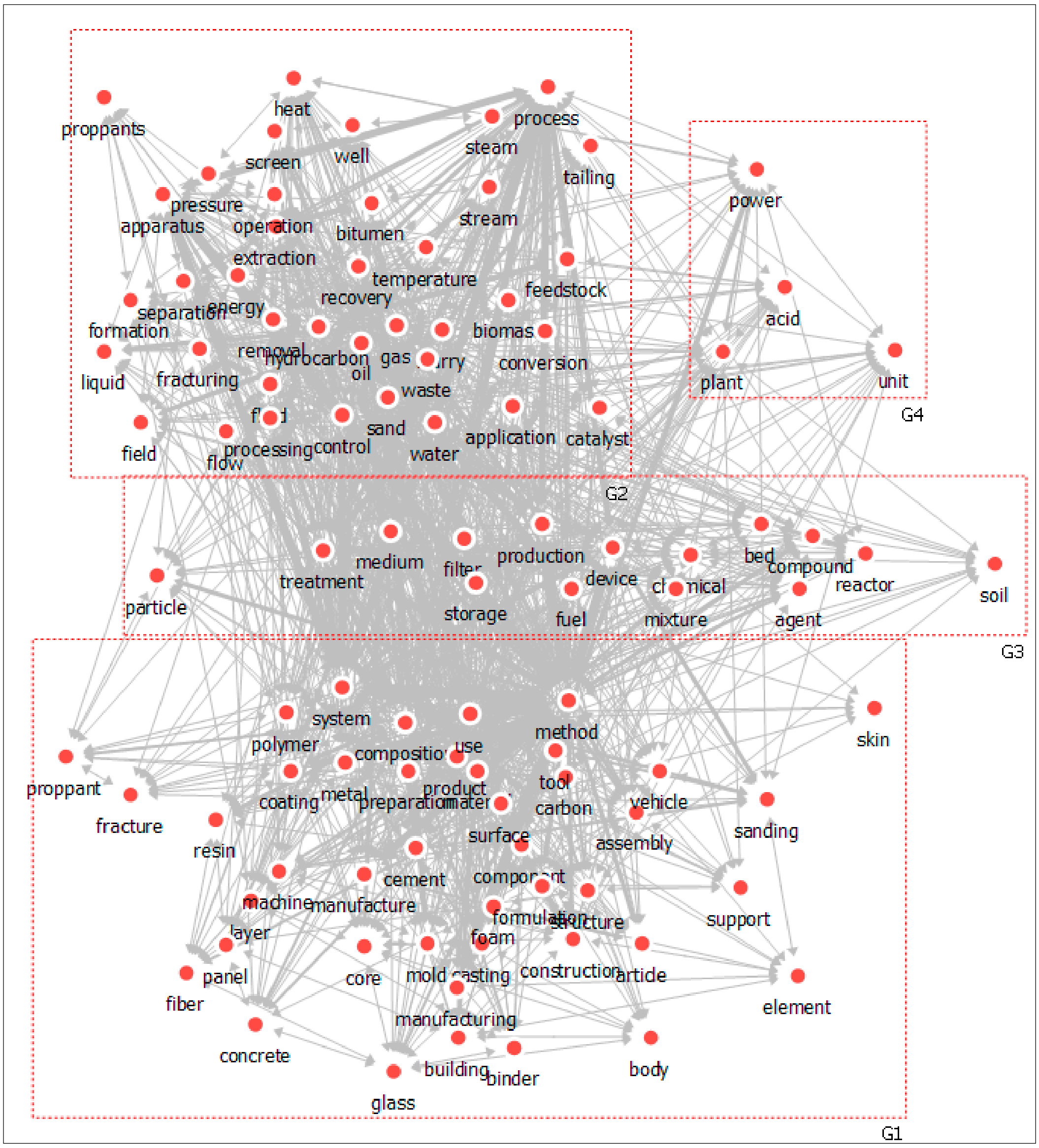


Figure 2. Group network analysis of digital oil fields.

The recently developed virtual field is a technology that can simulate the physical process by mathematically modeling a production network from oil and gas fields through a production line [27]. This is an important step, in which real time on-site data analysis, production optimization, and economic forecast analysis can be performed by incorporating risk factors into the simulation as well. Production optimization can be performed by applying each production classification; the optimization process utilizes additional drilling locations and plans at the field scale. Ultimately, this process can be integrated and used to predict oil price fluctuations or production volumes, thereby establishing an optimal management system for major oil fields [28].

> A device with one or more sensors for monitoring the effectiveness of sand compaction on a production line. The sensor measures the changes in sand compaction, which is affected by the mechanics of the vibration system, changes in the sand properties, and environmental changes—from patent #13204677, 2011.8.6. Moha**-.

The third group, G3, includes keywords such as "device", "treatment", and "production", and indicates major issues related to sensor and interface support. Device technologies include sensors and interfaces, and represent the processes of seismic exploration, 4D exploration, and monitoring, including remote sensing [29–31]. Processing and visualizing the obtained data can increase the efficiency of oil production by unifying complex data, such as geological and borehole data obtained from earthquake disasters, to increase the drilling and development efficiency.

G4, the last group, comprises major issues related to control hardware, such as the "plant", "power", "acid", and "unit". The major DOF companies characteristically develop technology mainly on the sea, where energy-related technology developments for plant management are being made. It has been confirmed that these companies are attempting to develop more efficient technology for situations where it is necessary to supply electricity to an offshore oil field.

A digital offshore plant field has also been analyzed. This field is used for discovering, drilling, and producing marine resources such as oil and gas, and is closely related to the DOF. Developments in this area can significantly reduce the cost of generating and producing marine resources in offshore plants by combining new technologies, such as ICT, with established ones [32,33].

In marine installations, a DOF is unmanned and remotely controlled. Owing to initial cost limitations, the technology for offshore oil fields tends to be developed mainly through collaboration with major companies that develop large-scale oil fields and major ICT companies. To disrupt the monopoly that major companies with experience in large-scale oil fields have, it is necessary to develop DOFs with differentiated strategies.

> A method for recovering gas in natural gas hydrate exploitation is disclosed, in which a gas–water mixture at the bottom of an exploitation well is delivered to an ocean surface platform through a marine riser by adopting the gas-lift effect of methane gas derived from the dissociation of natural gas hydrate, thus achieving a controllable flow production of marine natural gas hydrate. #15765652 2018.2.12. G* institute-.

Technological innovations in DOFs have evolved. Initially, in early 2010, keywords such as "oilfield", "gas system", "process composition", and "apparatus" ranked highly. A change was observed in the mid-2000s, and as the importance of devices that improved the process efficiency of DOFs increased, the ranking of keywords related to those devices also increased. In recent years, devices that are considered important in DOFs have been sensor, block chain, and predictive analytics technologies (Research and markets, 2018). Among these, sensor technology is central in data collection and processing, and plays an important role in the development of DOFs. To manage a large area, it is necessary to install a sensor, and collect and analyze its data; the economic feasibility of this can be determined based on the price of the sensor. As a matter of fact, sensor prices have been falling since 2010 ($0.66 per unit) and, at the time of writing, they have fallen to half their initial values [34]. It has been confirmed that DOFs are becoming more economically efficient owing to the drop in sensor prices and that the majority of the keywords are device-related issues. In the development of DOFs, sensors can collect different data and, by processing these data, increase the efficiency and predictability of the entire process, thus facilitating the development of a smarter oil field.

> A completion system for use in a well includes a first completion section and a second section. The first completion section has a sand control assembly to prevent passage of particulates, a first inductive coupler portion, and a sensor positioned proximate to the sand control assembly, which is electrically coupled to the first inductive coupler portion—from patent #14586375, S* cooperation, 2014.12.30.-.

Data integration, which involves collecting data from each step, is a comprehensive process that covers data collection and processing. Optimization, which improves business efficiency, is performed by varying the judgment and manipulation method according to the collection of information in the upstream stage. Intelligent drilling and completion is a process that extracts underground information in real time during drilling. It helps drilling technicians remove obstacles and optimize operations such as bending. Specifically, it helps in optimizing the productivity of boreholes during drilling through means such as monitoring the temperature and pressure through a fluid sensor. It also prevents accidents by facilitating the early detection of hazards.

Next, changes in the knowledge-based network structure were examined by extracting the frequency of keywords over time (Figure 3), based on the keywords extracted from the network by group. The variation of the DOF over time is as presented here. First, when considering the contents of related patents, the keywords related to "system" and "process" are located at the root. This has remained the same for almost a decade and it can be confirmed that, in the development of the DOF, technological developments related to improving the efficiency of these systems and processes are being made. Additionally, it has been confirmed that DOFs, which manage the entire cycle, tend to be geared toward the development of technologies for overall optimization rather than the development of specific technologies.

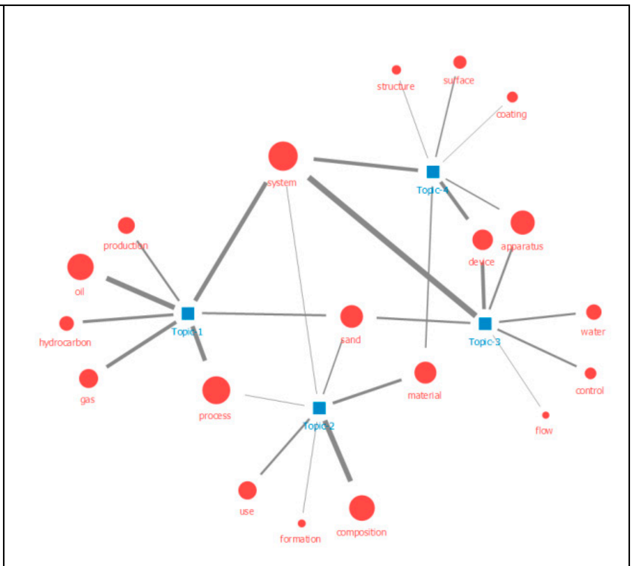
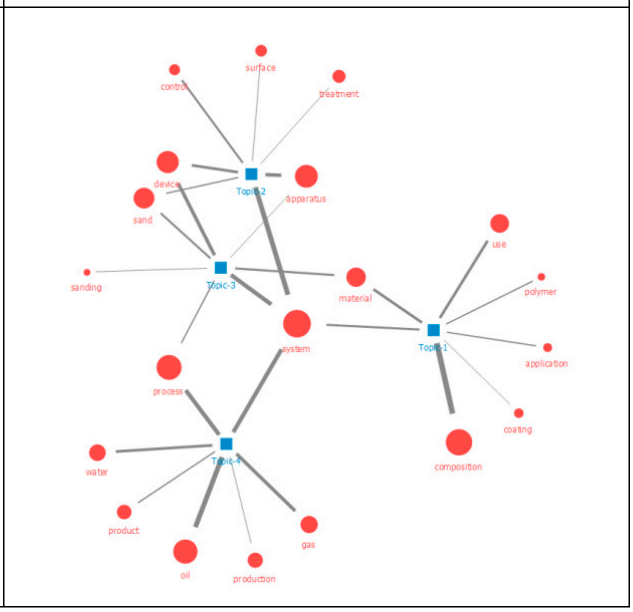
I(2011–2014)	
II(2015–2017)	

Figure 3. *Cont.*

III(2018–2020)

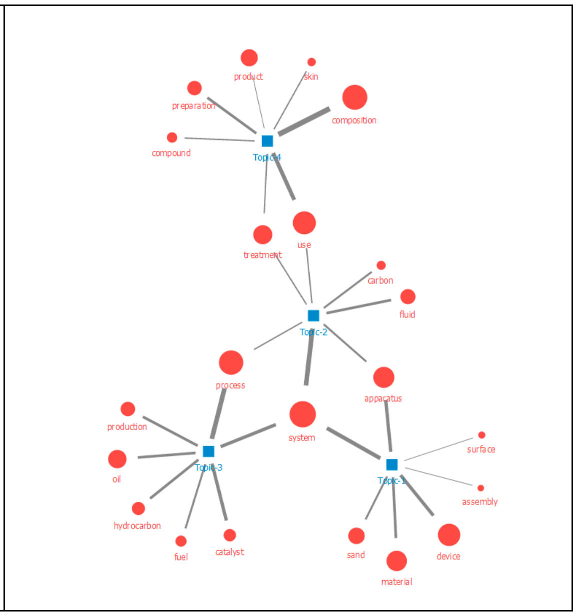


Figure 3. Result of topic modeling by time series.

In the development of DOF technology, "device" development is closely related to the sensor, communication base, decision support, remote operation, and control system fields. In the field of traditional petroleum resource development, which is mainly based on existing hardware device technology, it is possible to improve the economic efficiency of oil fields by adopting new ICT technology [35]. The core technology in this field is based on equipment components. Furthermore, hardware technology development is a field that has been developed in combination with AI and machine learning technologies that can support decision making [18].

The analysis results obtained from extracting the frequency of related keywords in the groups over time are detailed as follows.

The groups G1 (communications infrastructure), G3 (sensor and interface support), and G4 (control hardware) have become more important over time (Figure 4). The frequency of G2 (processing modeling), conversely, has reduced over time, indicating that the DOF has progressed beyond the initial stage of development, which requires overall process modeling. Furthermore, it can be observed that various technologies related to traditional oil resource development are evolving in combination with other innovative technologies as they undergo a scale-up process while being assimilated into the DOF. The technology related to G1 is advancing steadily, which suggests that the standards for maintaining interoperability by integrating different technologies are growing in importance over time.

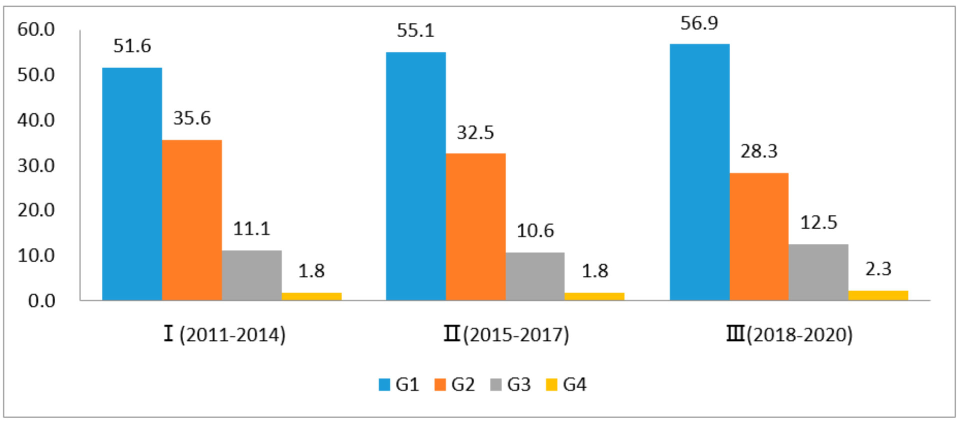


Figure 4. Characteristics of digital oil field (DOF) development by time series.

Groups G1, G3, and G4 have become increasingly important over time by percentage distribution. However, as seen in Table 2, the occurrence frequency of G1 key terms decreased from 5211 (2011–2014) to 4344 (2018–2020); the occurrence frequency of G2 key terms decreased from 3591 to 2158. The frequency ratio gradually decreases for all groups, but the distribution shows a tendency to increase gradually for groups G1, G3, and G4. This shows a tendency to decrease in quantity but increase in actual overall distribution, which is meaningful in that it shows qualitative growth of core technologies rather than a quantitative increase.

Table 2. Characteristics of DOF development by time series.

Group Division	I (2011–2014)		II (2015–2017)		III (2018–2020)	
	Frequency	%	Frequency	%	Frequency	%
G1 (Communications infrastructure)	5211	51.6%	4349	55.1%	4344	56.9%
G2 (Processing modeling)	3591	35.6%	2568	32.5%	2158	28.3%
G3 (Sensor and interface support)	1116	11.1%	839	10.6%	951	12.5%
G4 (Control Hardware)	178	1.8%	141	1.8%	177	2.3%
Total	10096	100%	7897	100%	7630	100%

4. Discussion

To develop a DOF, a strategic innovation transitioning from "data is the new oil" to "oil is the new data" is necessary. In the past, petroleum resource development involved oil production through the process of drilling, reservoir characterization, development, and the production of traditional oil. The oil industry, in particular, is characterized by the pervasive presence of cartels in the technology sector, as major corporations around the world dominate and lead technology development. Entering the petroleum sector, unlike other industries, requires high initial capital and experience. The availability of empirical data can reduce the opportunity cost and improve the economic efficiency of the DOF.

In DOFs, a technology that can increase the overall optimization efficiency is being primarily developed. In the petroleum field, petroleum technology developments so far can be mainly attributed to innovations in elemental technologies. However, the digital oil field is developing into a platform that enhances overall efficiency, focusing on the interoperability of element technologies [36]. Additionally, by using the data generated by the DOF platform, we are trying to realize not only the optimization of the entire system but also a reduction in management costs through the optimization management of the oil field. Therefore, in establishing policies related to DOFs, rather than focusing on specific technologies, it is necessary to focus on the overall system or control field and seek data-based support measures. In this field, the integration of different elementary technologies will emerge as an important issue in the future; technological innovation policy support is needed.

In the existing oil industry, the participation of venture companies and small and medium enterprise (SMEs) is restricted, owing to the monopoly of certain dominant companies. However, a situation where new technology is inevitable in the petroleum industry can provide a new opportunity for venture companies and SMEs with differentiated technologies to incorporate such new high-tech technologies into the market. Therefore, this study is meaningful in the sense that it offers a technological innovation direction for startups to enter into the oil industry, by providing the structural characteristics of the knowledge base of the digital oil field.

Digitalization of the oil resource development field is closely related to industrial development. Regardless of how good a technology is, if it does not yield industrial profits, it may be obliterated. Furthermore, technology in the field of petroleum resource development has developed under the monopoly of a few leading companies over the past few years; but there has hardly been any external technical impetus. A change in this aspect can provide an opportunity for the industrial revolution to shift to an oil-oriented development strategy centered on economics, especially against the backdrop of the surge in oil prices that occurred in the mid-2000s. A strategic approach is needed to shift the paradigm of energy-related technological development.

DOFs are being developed in tandem with various industries such as the parts, materials, equipment, and device industries; it goes beyond merely adopting ICT technology. Future studies could focus on confirming the development trend of DOFs in relation to the various industries in a development strategy focused on early productivity improvement methods.

5. Conclusions

In this study, using DOF-related patents, the technological innovations in DOFs, which have recently attracted significant attention in energy-related technology development, were analyzed. This study overcame the limitations of the existing patent analysis by focusing on the contents of the technology. Furthermore, research methodologies, such as the evolution of the technology field and cluster analysis through semantic network analysis, were utilized.

First, as can be seen in the DOF-related patent analysis, technological development is achieved through fusion with other industries, specifically the equipment, parts, and material industries. DOFs develop closely with the equipment, parts, and materials industries; they are not created by merely grafting new ICT into the traditional oil industry. It can be observed that developments are being made through innovations that go beyond simply monitoring the entire system; these developments do not involve merely deploying an ICT-based monitoring system in the existing oil resource development field. Therefore, to monitor the situation of oil and gas fields in real time and build an online management system by automating the entire process from exploration to production, it is necessary to go through the scale-up process of all related technologies and confirm that the overall technology optimization is taking place.

It is conjectured that the strategic preemption of the standard will emerge as an important policy task because standards must be established to ensure the interoperability of the elemental technologies in DOF technology optimization. In developing DOFs, it was confirmed that the main systems and processes are central to the interoperability of convergence technologies and closely related to standard preemption; technology development is being geared toward improving the efficiency of the component systems and processes of DOFs.

Several device-related technologies have also been developed. Among these device-related technologies, sensor technology provides new possibilities for the development of DOFs. This is because the development of sensor technology can lead to a qualitative growth in data collection and processing, as various data are produced and collected through sensors in DOFs. In terms of economics, the decline in the price of core devices plays an important role in the diffusion of DOFs.

Hardware technologies in the traditional oil resource development field are rapidly developing DOF devices, which is a deviation from traditional preoccupation, by combining AI and machine learning, data collection, and processing technologies. The core significance of this study is that it explains the evolution of DOF technology, which is illustrative of technological innovation in the field of energy-related data development and collection.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

This research focused on Oil resource development field development and production stage digital oil fields.

Table A1. Network analysis results of topic modeling analysis by time series.

No.	2011–2014			2015–2017			2018–2020		
	Keywords	Frequency	%	Keywords	Frequency	%	Keywords	Frequency	%
1	system	704	16.9	system	645	20.0	system	616	18.6
2	process	403	9.7	composition	300	9.3	composition	550	16.6
3	oil	366	8.8	process	266	8.2	process	373	11.3
4	composition	340	8.2	oil	250	7.8	use	240	7.3
5	apparatus	315	7.6	apparatus	229	7.1	device	215	6.5
6	sand	314	7.5	device	223	6.9	apparatus	209	6.3
7	material	288	6.9	sand	222	6.9	material	185	5.6
8	device	278	6.7	material	215	6.7	treatment	145	4.4
9	gas	211	5.1	use	168	5.2	oil	134	4.1
10	use	189	4.5	gas	166	5.1	product	131	4.0
11	production	176	4.2	water	124	3.8	sand	119	3.6
12	water	161	3.9	production	118	3.7	fluid	102	3.1
13	hydrocarbon	154	3.7	product	105	3.3	preparation	96	2.9
14	surface	145	3.5	treatment	101	3.1	production	96	2.9
15	control	124	3.0	surface	93	2.9	hydrocarbon	95	2.9
total		4168	100%		3225	100%		3306	100%

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