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디지털트윈에서 공간정보 역할에 관한 연구

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A Study on Geospatial Information Role in Digital Twin

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요 약 사물인터넷(IoT), 빅데이터(Big data), 인공지능(AI), 사이버물리시스템(CPS) 등 4차 산업혁명을 견인하는 기술들이 발전/보편화되고 있다. 이 기술들을 응용하여 다양한 산업 현장에서 생산성, 경제성, 안전성 등을 향상하고자 하는 요구가 확산되고 있다. 디지털트윈은 이러한 요구를 충족시키기 위한 중요한 기술 트렌드로서, 그리고 한국판 뉴딜의 10 대 과제 중 하나로 주목 받고 있다. 본 연구에서 구글 웹 검색기를 사용하여 논문, 매거진, 보고서, 기타 문헌을 탐색하였다. 디지털트윈 응용분야에서 공간정보의 기여 내용(또는 역할)을 조사하기 위해 디지털트윈의 정의·국내외 기업별 기술동향, 제조업·플랜트·스마트시티에서 요구되는 디지털트윈의 구성 요소와 디지털트윈 구동을 위한 핵심기술을 조사하였다. 그리고 공간 관련 키워드인 Geospatial Information, Geospatial data, Location, Map, Geodata와 디지털트윈 간 연계 문장이나 낱말을 탐색하여 공간정보의 기여내용을 정리하였다. 조사 결과, 공간정보는 단순히 사물-사물-사람-프로세스-데이터-제품을 연결하는 매개체로서의 역할 제공뿐만 아니라 신뢰성 높은 의사결정지원 · 연계융합 · 위치정보제공 · 프레임워크 등의 역할을 수행함으로 디지털트윈의 활용 가치 극대화에 기여할 수 있을 것으로 나타났다.

Abstract Technologies that are leading the fourth industrial revolution, such as the Internet of Things (IoT), big data, artificial intelligence (AI), and cyber-physical systems (CPS) are developing and generalizing. The demand to improve productivity, economy, safety, etc., is spreading in various industrial fields by applying these technologies. Digital twins are attracting attention as an important technology trend to meet demands and is one of the top 10 tasks of the Korean version of the New Deal. In this study, papers, magazines, reports, and other literature were searched using Google. In order to investigate the contribution or role of geospatial information in the digital twin application, the definition of a digital twin, we investigated technology trends of domestic and foreign companies; the components of digital twins required in manufacturing, plants, and smart cities; and the core techniques for driving a digital twin. In addition, the contributing contents of geospatial information were summarized by searching for a sentence or word linked between geospatial-related keywords (i.e., Geospatial Information, Geospatial data, Location, Map, and Geodata and Digital Twin). As a result of the survey, Geospatial information is not only providing a role as a medium connecting objects, things, people, processes, data, and products, but also providing reliable decision-making support, linkage fusion, location information provision, and frameworks. It was found that it can contribute to maximizing the value of utilization of digital twins.

Keywords : Digital Twin, Geospatial Information, Survey, Literature, Trends

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본 연구는 국토교통부 수요처 맞춤형 실감형 3D 공간정보 갱신 및 활용지원 기술개발 과제의 연구비지원 (21DRMS-B147287-04)에 의해 수행되었음
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1. 서론

디지털트윈(DT: Digital Twin, 이하 DT)은 스마트공장의 제품 개발 공정 다양화·테스트, 최적 운영 환경 구축, 스마트시티, 건설 및 부동산거래 시 도시를 현실감 있도록 표현하는 것을 지원한다. DT는 묘사·분석·진단·예측 측면에서 가치가 있으며(DHL, 2019)[1], 비즈니스 성과 향상, 창의성, 혁신적인 능력 및 효율성 향상, 마케팅 영업 및 고객 기반 서비스 및 관리 방법에 도움을 주는 것으로 알려져 있다.

Gartner는 2021 년까지 대기업의 50 %가 DT를 사용하여 효율성이 10 % 향상 될 것으로 예측하고 있다. Deloitte는 DT의 글로벌 시장이 매년 38 % 성장하여 2023 년까지 160 억 달러에 이를 것으로 예상했습니다[2].

'공간정보'는 지상 · 지하 · 수상 · 수중 등 공간상에 존재하는 자연적 또는 인공적인 객체에 대한 위치정보 및 이와 관련된 공간적 인지 및 의사결정에 필요한 정보를 말한다. 공간정보는 고객 기반과 관련된 문제, 추세를 이해하는 가장 좋은 방법이며, 비즈니스 · 사회 · 환경 · 스마트시티 · 농업 · 자율주행 · 드론 매핑 등이 공간정보를 통해 구현할 수 있는 주요 콘텐츠이다.

본 연구의 내용적 범위는 응용분야별 DT의 정의 · 국내외 기업 동향· 응용분야별 DT 구성요소 · 핵심기술 요소의 조사, DT에서 공간정보의 역할 탐색 등이며, 연구방법은 문헌탐색(인터넷 구글 검색) 기법이다. 특히, DT에서 공간정보의 역할 탐색을 위해 공간(지리)관련 키워드인 (Geo)spatial Information, Geospatial(ly), Geospatial data, Location, Map(s), (3D)Geodata 등을 이용하였다. 이 연구는 현재 4차 산업혁명 핵심기술, 한국판 뉴딜정책의 코어로 부각되고 있는 DT와 공간정보의 상호 연계 활용방안을 발굴함으로써, 미래 공간정보 산업의 먹거리 발굴 및 국가정책 수립에 기여하고자 한다.

2. 디지털트윈 정의 및 동향 분석

2.1 디지털트윈 정의

2002년에 마이클 그리브스(Michael Grieves)가 사용한 "디지털 트윈" 이라는 용어는 제품, 기계 또는 전체 생산 프로세스의 완전한 디지털 컴퓨터 기반 복제본을 의미한다[3].

DT는 사용자가 실시간 데이터를 기반으로 자산, 제품, 시스템 및 프로세스에 대한 변화의 영향을 사전에 시뮬레이션하고 테스트 할 수 있는 안전한 가상 환경을 제공할 수 있다. DT로 문제를 사전에 예측, 식별, 조기 개입하고, 문제 발생 전에 실수를 예방 할 수 있다[4].

Table 1은 각 응용분야에서 인용하는 DT의 개념에 따라 27개 참고 문헌을 모두 분류했다. 어떤 참고 문헌이 DT 개념의 정의를 제공하는지 여부를 살펴보았다. 전체 27개 참고문헌 중 약 1/2 만 DT의 개념을 포함하고 있다. 이를 통해 제조업, 항공, 스마트시티 분야가 DT를 잘 활용하고 있음을 알 수 있고, 자율주행차, 건설, 재해 등은 아직 걸음마 단계로 나타났다.

Table 1. Definition of DT for application domain

Application Domain	References	
Manufacturing	With definition	[5] [6] [7]
	Without definition	[8] [9] [10]
Aviation	With definition	[11] [12]
	Without definition	[13] [14] [15]
Healthcare	With definition	[16] [17]
	Without definition	[18]
Smart city	With definition	[19] [20]
	Without definition	[21] [22] [23]
Autonomous Vehicle	With definition	[24]
	Without definition	[25]
Infrastructure(e.g. construction, water)	With definition	[26]
	Without definition	[27] [28] [29]
Etc.(e. g. flood)	With definition	-
	Without definition	[30] [31]

2.2 기술동향

2.2.1 국외

본 항에서는 제조업, IT분야, CAD/CAE, 스마트시티, 연구소/대학교 등을 중심으로 DT의 활용분야를 조사하였다.

제조분야에서 GE, Siemens 등이 엔진, 발전기 관련 솔루션, 3D CAD/CAE 분야에서 Ansys, PTC, Autodesk 등이 제품수명주기관리(PLM: Product Lifecycle Management, 이하 PLM) 기반의 디지털트윈 솔루션을 개발하고 있다. IT분야는 IBM, Google, MS, 알리바바와 화웨이 등이 IoT, 네트워크, 인공지능, 빅데이터, 드론을 기반으로 한 상품을 개발하고 있다. 스마트시티 분야에서 Dassault, Cityzenith, ESRI, 그리고 Digital Twin technology 등이 DT를 구현하고자 한다.

MIT Media Lab, CSIC(Cambridge Centre for Smart Infrastructure, 이하 CSIC) and CASA(The

Centre for Advanced Spatial Analysis, 이하 CASA) 등은 DT 응용분야 발굴, 디지털구축 방법, 공간분석 기법 및 시뮬레이션 모델 등을 연구하고 있다. 항공분야, 의료분야, 농업분야, 로보틱스, 혼합현실 등 다양한 분야와 연계 및 활용 되고 있다.〈Table 2〉

Table 2. Application domain of Digital Twin (International)

Application Domain	Contents
Manufacturing	·Ship/offshore plant, pipeline, electric grid(DNVGL)(e.g.Veracity)[32] ·Blast furnace digital twin(Hatch)[33] ·Generator(e.g.Predix-GE,MindSphere-Siemens) [34][35] ·Oil refinery/petrochemical plant (e.g.Predix-GE, MindSphere-Siemens, Uniformance-Honeywell,TrendMiner-Total [36][37])
IT	·Presenting a solution applying AI, blockchain, and IoT to build a data-driven city(e.g.Watson IoT platform-IBM, Azure Digital Twin-MS) [38][39] ·Platform for IoT(e.g.Cisco, AT&T) [40][41] ·AI-enabled digital Twin(e.g. Huawei, Alibaba) [42][43]
CAD/CAE	·Digital twin of PLM(e.g.ANSYS Twin Builder, Siemens PLM) [44][45] ·Digital twin solutions for support in architecture, engineering, construction, and drafting (e.g.Autodesk University) [46] ·Industrial IoT(e.g.PTC ThingWorx) [47]
Smart City	·'Smart World Pro' for Digital twin platform for building(Cityzenith) (e.g.Amaravati smart city) [48] ·'Open cities planner' for designing, visualizing, and communicating projects from large-scale city developments to detailed architectural design(Bentley) (e.g.Kalasatama smart city) [49] ·3D visualization software for Urban Planning "Cityware" (Digital twin technology) [50]
Lab.& Academy	·MIT media lab: CityScope - a rapid prototyping platform for urban planning) [51] ·CSIC: Innovation and Knowledge Centre [52] ·CASA: Centre for Advanced Spatial Analysis [53] ·LuXDEM: Luxembourg XDEM Research Center [54]
Etc.	·The living heart project (Dassault Systems) [55]
	·Medicine [56]

2.2.1 국내

포스코, 삼성SDS, LG CNS, 현대위아, 고리원자력발전소, SK Telecom 등 많은 대기업은 제조업분야, 한국국토정보공사와 한국토지주택공사는 스마트시티 사업, 그리고 한국전자통신연구원, 한국건설기술연구원, 한국전보통신기술협회, 한국농어촌공사, 정보통신산업진흥원 등은 디지털트윈 마스트플랜 수립, 디지털트윈 설계, 중장기로드맵 수립 용역 등을 수행하고 있다. 용역의 주요 내용은 메디컬, 사회문제, 교육, 제조, 산림, 방사성폐기물, 댐 등 다양하게 나타나고 있다. 국토지리정보원과 한국농어촌공사는 DT기반 지형정보와 3D 공간정보 제작 관련 용역 및 연구를 추진하고 있다. 서울시는 '버추얼 서울', 세종시는 세종 5-1 생활권에 ETRI와 함께 DT를 구축 제공할 예정이다. 의료분야, 혼합현실 등 다양한 분야와 연계 및 활용 되고 있다. 〈Table 3〉

Table 3. Application domain of Digital Twin (Domestic)

Application Domain	Contents
Manufacturing	·Smart factory platform 'PosFrame' : steel product production(IXOtive) [57] · 'Intelligent Factory' : driving platform-based manufacturing intelligence(Samsung SDS) [58] ·Integrated Smart factory platform 'FACTOVA' : manufacturing ICT platform(LG CNS) [59] ·Smart factory solution 'iRiS': integrated management of machine tool SW, control and monitoring system(Hyundai-Wia) [60]
Smart City	·Jeonju smart city project(LX) [61] ·Sejong Digital Twin DB construction and master plan establishment (LH) [62] ·National Pilot city - Busan Eco Delta Smart City (MoliT) [63] ·'Virtual Seoul project' (Seoul) [64]
Lab.& Academy	·BAS(Big data+AI+Simulation)' technology development(KDTLab) [65] ·Department of Smart Factory Convergence, Sungkyunkwan University(SKKU) [66]

DT의 응용분야를 고찰해보면, 국외는 이미 제조업(특히, 대기업) 중심으로 DT를 도입하고 있으며, 스마트시티로 확장되고 있음을 알 수 있다. 국내는 일부 대기업이 제조업 중심으로 DT를 활용하고 있는 단계이다. 스마트시티에 DT를 도입·시도하고 있는 실정이지만, 전반적으로 DT의 적용은 미진하게 나타나고 있다.

3. 디지털트윈 구성 요소

3.1 응용분야 관점

DT는 기술이 아니라 응용서비스라는 관점으로 볼 필요가 있다. 기술들을 종합해서 사용성이 높은 서비스로 만드는 것이 핵심이다. 디지털트윈을 구성하는 기술요소는 어떻게 이것을 구성하느냐에 따라 달라진다. 〈Table 4〉

Table 4. Components of digital twin in application domain

Application domain	Components
Manufacturing	·Sensors, Data, Integration, Analytics, Digital twin, Actuators [67]
	·A data model, A set of analytics or algorithms, A set of executive controls [68]
Plant/fleets	·Physics based models, AI, Next generation sensors technology, Digital Thread [69]
Smart city	·Big data & IoT in smart cities, Sensors, 5G connectivity, Geospatial technology, Robotics [70]
	·Cyient: 3D GIS platform with data model geotagged to every device, including hydrophones, HD cameras and drones ·Noesis: Acoustic sensors identify and localise entries ·TerraGo Technologies: on-demand search lighting for authorised emergency personnel ·UniqueID: connected lifebuoys to detect emergency or misuse, and blinking public lights to help the coastguard rapidly identify the exact emergency location [71]
	·Koya Digital: utilised IoT and AI to monitor, predict and influence, the flow of large groups of people travelling through urban environments ·TerraGo Technologies: on-demand traffic signal control to improve mobility around high-traffic events [72]

Table 4는 응용분야별 DT 구축 시 필요한 기술 구성요소를 정리하였다. 가장 많이 등장하는 요소는 데이터(모델포함) 4회, 센서 4회, IoT 2회, AI 2회 등 이다. 그리고 응용분야 별 특성을 반영한 요소로 식별자, 제어, 신호등도 포함되어 있는 것으로 조사되었다.

3.2 핵심기술 관점

Table 5는 디지털트윈 구동기술(enabling technologies) 목록을 나타내고 있다. IoT 4회, AI(Learning, ML 포함) 4회, 데이터(빅데이터, 데이터 분석, 통합 등 포함) 11회, 클라우드 4회, 센서 4회, 모델 4회, 시뮬레이션 3회 등 4차산업혁명시대의 대표적 기술들이 모두 포함되어 있음을 알 수 있다. 기타 내용으로 연결, 가상현실/증강현실/혼합현실, 3D 프린터, 시각화, 엑츄에이트 등이 포함되었다.

Table 5. Components of enabling technologies of digital twin

References	Components
DHL	· IOT, Cloud computing, AI and advanced visualization technologies [73]
IT-KSC	·3D scanning, VR, AR, MR, IoT, Cloud, Big data, 3D printer [74]
Gill	·Data, IoT [75]
Altran	·Connectivity&Networks, Data Intelligence, Simulation, Advanced HMI, Scalable Elastic Knowledge Graph [76]
Fuller et al.	·Application domain: Model architecture and visualisation, Software and APIs, Data collection and Pre-processing ·Middleware Domain: Storage technology, Data processing ·Network Domain: Communication technology, Wireless communication, Hardware platform, Sensor technology [77]
Tao et al.	·Cloud Platform, Cloud Computing, Security, Sensors, Software, CAD, 3D Model, Data Analytics, Data Integration, Data Visualization, AI, Simulation, VR, AR, Actuator, Connectivity [78]
Maria	·IoT, ML, AI, Big data ·Model of the physical object, Time series data, Unique identifier, Monitoring capability [79]
Qi et al.	·Physical, Model, Data, Connection, Service [80]
intellias	·Velocity, Resolution, Learning [81]
Wired Brand Lab	·Simulation software and tool, the enabling force of all those sensors, the emerging power of machine learning and predictive analytics in systems [82]

응용분야와 핵심기술 관점에 따라 DT구성요소는 상이하게 나타났지만 데이터, 센서, IoT, AI는 등은 공통 기술요소로 등장하였다. 향후, 분야별 DT 구축시 무엇보다 이 분야에 인력과 예산투자가 필요할 것이다.

4. 디지털트윈에서 공간정보의 역할

Table 6과 같이 공간관련 키워드인 (Geo)spatial Information, Geospatial(ly), Geospatial data, Location, Map(s), (3D)geodata를 사용하여 DT에서 공간정보의 역할(기여)을 조사 하였다.

조사결과, 공간정보는 의사결정지원, 데이터 수집·변환 등 정보기술의 연계·융합을 위한 핵심 요소, 프로젝트 프레임워크 제공, 위치인식 지원 등 다양한 역할을 하는 것으로 조사되었다.

Table 6. Role of Geospatial Data for digital twin

Key points	References
(Geo)spatial Information	·With DT: [83] [84] [85] [86] ·Without DT: [87] [88]
Geospatial(ly)	·With DT: [89] [90] [91] [92] [93] ·Without DT: [94] [95] [96] [97]
Geospatial data	·With DT: [98] [99] [100] [101] ·Without DT: [102]
Location	·With DT: [103][104][105][106] [107][108][109][110] [111] ·Without DT: [112] [113]
Map(s)	·With DT: [114] [115] ·Without DT: [116] [117]
(3D)Geodata	·With DT: [118] [119] ·Without DT: [120] [121] [122]

Fig. 1에서 보는 바와 같이 공간정보는 기술, 응용분야, 시스템, 그리고 DT 개념과 융합을 통해 다양한 시너지를 창출할 수 있다.

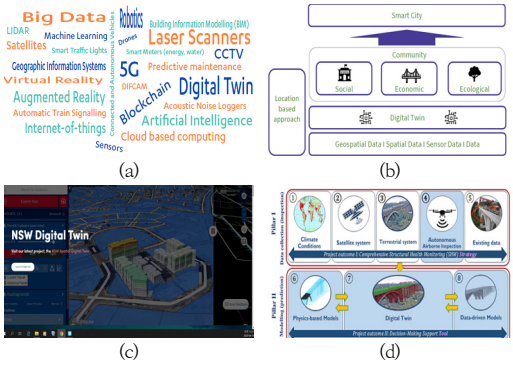

Fig. 1. Examples of DT-Geospatial Information fusion (a) DT construction technologies[123] (b)Smart city [124] (c) NSW DT [125] (d) DT concept [126]

5. 결론

이 연구는 문헌조사를 통해 DT구축 시 공간정보의 역할(기여)을 탐색하고 다음과 같은 결론을 얻었다.

1. DT정의는 응용분야에 따라 상의하지만 virtual representation, computerised version, computer-based replica, advanced(living digital) simulation, virtual model 등의 DT를 직접간적으로 표현하는(암시하는) 단어를 포함하고 있는 것으로 나타났다.
2. DT구성요소는 응용분야 관점에서는 데이터 모델, 알고리즘, AI, IoT 등 기술과 UniqueID, Lighting, Traffic signal, Acoustic sensors 등 응용분야 특성을 고려한 요소로 구성되는 반면, DT구동을 위한 핵심기술은 IoT, Cloud, Data, Simulation, Visualization 등 기술 중심으로 구성되어 있다.
3. 공간 관련 키워드를 이용한 문헌조사 결과, DT에서 공간정보의 역할은 명확하지 않지만 의사결정지원(상황 또는 현상의 이해), 연계융합, 위치정보제공, 프레임워크 구축 지원, 인프라 복원력 증대 등에 기여하는 것으로 조사되었다.

향후 공간정보는 DT를 기반으로 기하-속성, 응용분야-응용분야, 사람-사물-기계-프로세스 등의 연결 매체자로서의 역할이 확대될 것이다. 또한 미래의 Intelligent DT 도래에 대응하기 위한 새로운 공간정보(데이터 포맷, 플랫폼 아키텍처, 사용자 참여서비스, 콘텐츠 등)의 변화가 요망된다.

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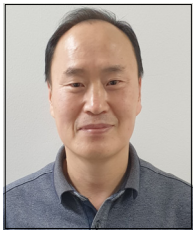

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