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From Digital Document To Digital Twin Towards Networked Knowledge and Culture

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Abstract

Digital twin for everything has been proposed as a novel idea to implement digital transformation in the 4.0 era. Beyond the industrial applications, more 80 experimental prototype systems have been developed by the author so far to demonstrate its feasibility and general availability for applying digital twins in cultural heritage and knowledge dissemination areas. A universal methodology is developed based on knowledge-graphs and future Internet technologies to implement a goal-oriented resources integration and provide high-value cultural knowledge and Cultural (K&C) cloud services, which can be co-created and shared by people, towards building an ideal K&C ecosystem. The digital documentation tool as a natural candidate has been rediscovered its value in building digital twin for knowledge and culture. This will result in a new K&C infrastructure in the networked knowledge and culture era and trigger a very prosperous market of digital K&C products.

Keywords: Digital Twin, Digital Twin for Everything, Knowledge Graph, Internet of Knowledge, Knowledge Cloud, KaaS, CaaS, Rediscover Digital Documentation Tools

1 DIGITAL TWIN - A CORE TECHNOLOGY FOR DIGITAL TRANSFORMATION

Transfer from paper media to new digital media marks a significant progress of human civilization. Appearance of digital document tools provides a novel carrier for digital representation of knowledge and culture, just a first step towards digital transformation of knowledge and culture. Appearance of paper and printing proudly known as great Chinese inventions which brought a glorious moment in ancient Chinese civilization. Facing with an important historical turning point of moving towards the networked knowledge and culture era, we must come up with our insightful ideas and actions without losing any time to catch up the new pace of progress in human civilization through speeding up scaled dissemination of knowledge and culture. Promotion from digital document to digital twin is just a novel solution for such purpose highly recommended in this paper.

While marching towards the digital transformation 4.0 age, accelerating development process through digital technology has become a must-be action today. This involves almost all aspects, including the industrial transformation in building smart factories and products, as well as the digital transformation of cities and organizations, of course, don't forgetting the vital intelligent driving force: knowledge and culture. For those purpose, the digital twin technology is undoubtedly the most natural selection as a key core technology in the digital transformation era, in which a virtual replica of a physical asset in the real world is built to purposely introduce the DIKW hierarchy for enabling IT processing to make smart and automation possible. Nowadays Digital Twin for Everything and Digital Twin Everywhere have become frequent and fashionable topic, however, feasible solutions are expected for real practice.

Knowledge as primary resource in the knowledge economy and culture as important social driving force have been self-evident common sense. Today they also face urgent needs for

digital transformation to give full play to their due driving value. Building digital twin for knowledge and culture is the research objective pursued by the author of this paper for a long time. A feasible methodology has been developed and its universality and availability have demonstrated by dozens of application prototypes. This is also a beneficial first step towards building digital twin for everything [1].

Implementation of digital twins needs to rely on two key technologies. One is digital modeling and simulation. For knowledge and culture, we proposed use of the knowledge graph for digital modeling to embody their internal semantics and unique relevance, and running simulation based on ready-made functions built in current digital document tools. The underlying network support is another key technology needed for building digital twin. For the industrial area, it mainly depends on the Internet of things (IoTs) and Industrial Internet, unfortunately that are totally not useful for virtual concepts in the knowledge and culture. Here a clever solution is borrowed from the idea of the **Internet of Everything** (IoE), more specifically, a set of future Internet technologies, they are: Internet of Knowledge and Contents (IoK, IoCs), Internet by and for People (IbFP), and Internet of Services (IoSs), by which all relevant contents and resources can be integrated into an organic whole, small services linked to be a large service, smaller digital twins converged into a larger one. All of these are performed merely by simple connectivity of the Internet without any complex software interface. Meanwhile, it also has an indispensable characteristic in supporting crowd-creation and sharing.

Finding the possibility of only utilizing off-the-shelf functions of digital document tools for building digital twin at first time made us feel very lucky and unexpected. After a little reflection, we gradually realized that this is quite natural and not an invention owned by us. In fact, the original intention from Microsoft in developing the digital document tools was to explore the new media for digital transformation of knowledge and culture. As a result, some application support functions possibly useful have been naturally deployed and considered in advance. This happened to give us a chance to smoothly return the original intention in exploring new knowledge and cultural applications.

2 FROM DIGITAL DOCUMENT TO DIGITAL TWIN

Organizing knowledge and Cultural resources based on digital twin, although its carrier used is still same digital document, while looking at its implementation and service objectives there are qualitative difference and improvement that can be illustrated in following two aspects.

So far digital documents have been widely used in digital publication of knowledge and cultural contents. Although a general picture can be learned a little bit from its title/abstract/TOC and keywords, to grasp it completely a patient consulting and full-text reading are often inevitable. For some parts the page text couldn't fully cover, it needs additional lookup and reading the indexed original literatures by yourself, a frequently time-consuming job. In this sense, a digital document is merely a textual copy of its printed book or paper.

On the contrary, the digital twin contained same contents is perfectly different. It can be understandable and processed easily by both people and computer due to built-in digital model with the knowledge graphs. Via its cloud address, it can be conveniently accessed and openly shared. When reading it, by navigating with the knowledge graph, the reader can more effectively find out its main points and essentials and quickly locate the spots interested, and then by a simple click on the respective icon to acquire linked resources. In this sense, a digital twin is no longer just a copy of document, more be a complete embodiment of specific piece knowledge contained in the text. More important, it can be re-located in a larger context via its inherent superlink address to present it in a more complete knowledge or cultural framework.

More interesting and practical, the digital twin method can be applied to develop a valuable goal-oriented knowledge and cultural service. Facing with a fast changing era of information explosion and rapid technology development, a passive method of just waiting for resource mining should be completely abandoned, instead, it should be an *active* goal-oriented and well-organized professional service to integrate all necessary resources and directly send them to who demand. Based on the served objectives, a professional knowledge auditing is performed to identify knowledge gaps achieving the goals and formulate the digital twin landscape required through digital modeling. Then based on that, all required resources are

collected and organized into an integrated framework. With this method, the knowledge or cultural resources have been converted to a more purposeful active service, embodying Knowledge as a Service (KaaS) and Culture as a Service (CaaS). From the user's perspective, this looks like a goal-oriented professional knowledge or Cultural repository. Once all these have been stored in the public cloud, it will deliver a so-called 'knowledge cloud' or 'Cultural cloud' service shared by everyone with a mobile terminal. Some experts claimed that as "The Future of the Future" [2]. We also call it as a new infrastructure – '*Knowledge Superhighway*', succeeding to the Information Superhighway, facilitating millions of professionals stepping in a highway towards the knowledge peak [3]. From the perspective of development and implementation, this looks like a factory that can provide customized knowledge or cultural products and services and strictly follows the RPV innovation model [4], i.e. based on the resources R required by the served objective, design an appropriate building process P to provide the requested service value V. The goal-oriented approach ensures accurate and unique value proposition. Supported by professional services, the domain expertise can assure effective and optimized resources organization. High integration of all available resources may facilitate maximization of service value.

Based on the above discussion and understanding, we propose it's just a good time of returning to the original intent in developing digital document tool, to be a true valuable tool in building digital twin for knowledge and culture. The digital document is not just a substitute for paper in new media, more to be a direct knowledge/cultural product or service, as well as a knowledge/cultural repository with enough resources. Each digital twin is active in the cloud with its unique superlink address, serving as an organic component node in the IoK and IoCs.

3 DIGITAL-TWIN BASED PUBLIC KNOWLEDGE & CULTURAL SERVICE SYSTEM

In 2012 the IFLA published a trend report [5], giving an extremely important factual data: "In 2010, the quantity of information transmitted globally exceeded 1 zettabyte for the first time, and is expected to double every two years. The amount of new digital content created in 2011

amounts to several million times that contained in all books ever written. OECD figures show that Internet traffic has risen by 13,000% in the last decade, with more digital information created in 2008-2011 than in all of previous recorded history.” Facing with such an information explosion trend, it puts us on a very serious topic: how can effectively dig such a knowledge treasure and meantime avoid being caught in the tide.

Nowadays, the Internet has become the main information channel that people are used to rely on. They prefer to finding simple answers to questions quickly, that brings many drawbacks and risks as the Internet is full of fake news, false facts, fake experts and pseudo-knowledge. It also caused the fragmentation of knowledge. In the worst case, the Internet may also make people more blind and stupid. Although search engines are still useful tools, as pointed out and warned in the IFLA report: “The algorithm has all the answers, - so what’s a library?”. To avoid knowledge overload and crisis, David Weinberger, a leading thinker about the Internet, recommended in his famous award-winning book “Too Big To Know”: “Building The New Infrastructure of Knowledge” [6]. According to the author, building the digital twin library (DTL) will be a timely selection in this direction, also a smart choice towards digital transformation of the library, that can act as a public knowledge and cultural service platform serving for development needs of the whole society.

The resource management in the digital twin library no longer only focus on the collection of books and literature documents. It’s more concerned how to build digital twin of knowledge and cultural achievements, without any border restrictions, integrating all valuable resources in the Internet based on their semantic connotation and relevance. Therefore, it has unique abundance as all-inclusive and best use of everything, able to support more valuable application services. Let readers see not only the wood but also the forest as well as all possible linkage, easily grasping the integrity and relevance of knowledge. By that main role of the library is turned from previous resource management to higher-level knowledge and cultural management.

From the service perspective, the DTL, totally going beyond simple resource classification and book lookup & loan service, provides active and in-time professional knowledge and cultural services to meet specific development needs. It’s more like a market-driven factory producing

customized knowledge and cultural products on-demand. In the DTL, there are a number of virtual reading room with specific topic in with what readers can find is really a professional knowledge or cultural repository with complete well-organized resources. This is a last mile of active pushing service to facilitate the transformation of knowledge and cultural resources into a real intelligence-driven engine for society development. It also puts on higher requirements for librarians who should become a qualified professional librarian and consciously to be a member of a KIS/KIBS industry, moreover, be good at identifying and attracting domain experts for cooperative participation in co-creating the digital twins.

The digital twin method has very strong universality. It's possible to build digital twins for all domains of knowledge based on their inherent body of knowledge to realize a real-time and dynamic summary of available cognitive achievements. By this approach, the front-line workers can record their recognition and experience in knowledge discovery and exploration, convenient for others to learn from. The high scalability of knowledge graphs perfectly adapts to such kind of dynamic evolution. Therefore, the future DTL is likely to be an all-encompassing knowledge and cultural treasure house for human being, a large ecosystem for promoting continuous prosperity of knowledge and culture.

Nowadays the mobile phone has greatly changed our daily life. A large number of 'mobile phone controls' make free time indulge in browsing boring information. How can turn back such a situation to make this space more knowledgeable? It is assumed to turn the mobile phone screen into a 'hole-in-the-wall for self-learning' [7] in hand, through building the digital twin library, to provide one door access to the knowledge and cultural treasure house and return free time for acquiring and co-creating valuable contents, which would create a 'Cognitive Surplus' expected by Clay Shirky [8], to greatly accelerate social progress.

4 SOME INTERESTED APPLICATION PROTOTYPES

Building digital twin for smart factory demands a high technical threshold. Building complex digital twin city will meet more challenging issues, such as urban brain and digital nervous system, 3D urban modeling and simulation, etc. It's by no means a day and night work and

requires very high R&D investment. The digital transformation of knowledge and culture is also an indispensable and important part in urban development. But its technical threshold is much lower than those mentioned above as a feasible methodology has been developed by the author. It's no longer on paper, but something within reach. As a rather uniform and cost-effective approach, you only need to draw inferences from application promotion as well shown in the following application prototypes.

Towards a pragmatic method to avoid stopping at a mere paper talk, we have developed so far 45 prototype applications in cultural domain to show its feasibility and applicability as well as application value. These pilot projects can be categorized into various types as shown in the table 1.

Table 1 Cultural Digital Twins

Type	Number	Representative Cases
Museum	4	Haihunhou Ancient Tomb Excavation The Root of Shanghai: Guangfulin Relics
Chinese Civilization	1	Distant Source & Long Stream
Regional Culture	6	Shanghai (Haipai) Culture & Red Culture
Intangible Cultural Heritage	2	Chinese ICH Resources
City Planning & Development	7	Shanghai - Global Excellent City By 2035
Characteristic Town	13	XinChang Ancient Town
Brand Building	3	Shanghai's Four Brands
Famous Person's Spirit	1	Chinese Playwright Cao Yu
Cultural Tourism	8	World Reception Hall in Shanghai

4 museum prototypes illustrated that the digital twin will be a feasible approach for building virtual museums to 'make museums and relics come alive' an objective specified in the national action plan for "Internet + Chinese Civilization". Constrained by physical space, only partial relics can be exhibited in turn by current museums. Contrastingly the digital twin museum makes all items exhibition possible on a 24x7x365 basis. It can support not only real

exhibits but also stories behind with accessible illustrative resources linked.

The regional culture is essentially an abstract macro concept, always giving a vague and elusive feeling. Interestingly enough, after building a digital twin for Shanghai and Zhejiang culture [10], we surprisingly found the replica in the cyberspace had become full-fledged and ‘visualized’, giving readers more intimate and realistic feeling, knowing what contents these culture have and helping in additional study with rich resources linked. This is probably the benefit from combining virtual and real thing.

How can transform China from a labor-intensive country into a talent-driven power nation ? It needs a out-of-the-box thinking to build an extra-wide channel for fostering millions of professional talents for each domain in meeting the needs of industrial development. Only squeezing into a single-plank bridge towards high schools has become a hard bottleneck in China. Moreover, knowledge update of on-the-job workers cannot compete with tight university’s resources by the same reason. Building digital twin majors on Internet will be a new shortcut to cultivate professional talents. Learning resources are well organized by the domain Body of Knowledge (BoK) which specified the required knowledge and skills of a qualified professional.

Based on this idea, we have developed 39 digital twin prototypes for domain knowledge, including some hot information technologies such as cloud computing, IoTs, Big Data etc. The following table give some examples related to software engineering techniques:

Table 2 Digital Twin Majors for Software Engineering

Body of Knowledge	Sponsor	Books Linked
Software Engineering SWEBOK v3	IEEE, ACM	3825
Project Management PMBOK	PMI	655
Software Quality SquBOK	JUSE	427
Software Testing ISO/IEC 29119	ISTQB	927
Agile Development ADBOK	CASDA	506

Software Process Improvement SPIBOK	IISP	722
Service Science, Mgmt, Eng, Design SSMED	IBM	405
Service Computing BOK	IEEE	610

In recent years, the MOOC (Massive Open Online Courses) model is changing the educational landscape and rising as an educational innovation, promoting globalization, open access, and democratization of knowledge. The digital twin solution proposed in this paper has a general sense in resources linkage, thus covers naturally the MOOC as well. In fact, the digital twin approach adheres to same principles, like Massive, Open, Online i.e. MOO, but with more resource types available, so that we can call it as MOOK/C (Knowledge/Contents) and MOOL (Learning), promoting a paradigm shift from “Teacher-Centered” to “Learner-Centered” [9].

The digital twin knowledge approach can also be applied to provide active knowledge services dedicated to the national strategic development projects. The following table shows some prototypes developed already:

Table 3 Goal-Oriented Active Knowledge Services

Project	Books Linked
Marine Economy	8439
Made in China 2015	6964
Internet Plus Action Plan	10217
National Security	1407
Urban and Public Governance	7604
Innovation Techniques and Methods	1304
New Product Development	1300

Here each application looks like a domain-specific knowledge repository in a special reading room of the DTL, which tell in detail what should to do and know and where can find and get required knowledge to implement the project.

To help tracking and learning vital emerging technologies, writing a technology survey or review is a normal approach. However, reading a lengthy report always puzzle readers to reach points and for studying further details looking up original literature often is an extra must. To build a digital twin for the survey report is a value-added recommendation. It acts as a novel knowledge repository, able to reuse all survey efforts. Guided by the knowledge graph, readers can quickly find out their interesting point and then directly get the original paper by a simple screen hit even on a mobile phone. Undoubtedly this kind of digital-twin-based knowledge repository will be a very useful way in speeding up new knowledge dissemination. The following table shows two practical examples developed:

Table 4 Digital-Twin Based Knowledge Repository

Repository Name	Indexed Literatures
Trusted Software System Engineering	765
Social Risk Governance in Megacities	580

5 EMERGING NETWORKED KNOWLEDGE & CULTURAL MARKET

All prototypes developed so far were dedicated to verifying feasibility and availability of the proposed approach, a typical problem-driven process. Endless requirements for new applications stimulated us emerging creative inspiration and continuous exploration in many unfamiliar domains without any cessation until 86 prototypes produced. No need to own, all creative ideas and materials come from readily available online resources. The goal is the driving force and content is king. This is perhaps a feature of the digital transformation era, existing so many opportunities to be explored, for which building digital twin undoubtedly is the most natural and straightforward approach, a source of creation.

All prototypes delivered are not the final product that are just used by us to cast a brick to attract jade, enlightening what can be really done. We took the first step in a new domain with a belief “No best only better”. With the participation of domain experts and wide support from the community of practice (CoP), the product or service will become more and more mature

and perfect.

As knowledge and cultural elements have permeated into each aspect, it brings an extremely wide application spectrum to our approach, what have deeply experienced in developing our prototypes. Nothing can't be done, only not imaged. With continuously emerging new development goals plus knowledge discovery, it will bring inexhaustible sources of creation and trigger a very prosperous digital knowledge and cultural product market.

In recent years, the knowledge graph (KG) is becoming a hot spot as the cornerstone of AI technology to be used for automatic discovering new knowledge through mining large volume of unstructured data. This can be considered as a 'bottom-up' reasoning approach by seeking for correlations between information entities. When using the KGs in defining digital twin, we adopt a reverse strategy, that is, to reuse the implicit knowledge of domain experts through a 'top-down' approach by which the inherent semantics of the target digital twin can be explicitly elaborated by a layered of knowledge graphs. This can be considered as a live summarization of object knowledge that is highly succinct and complete. Here the KG is equal to a knowledge modeling tool of digital twins and the defined KGs can be viewed as a digital architecture of specific object. Although mining and discovering new knowledge through big data analysis is a very interesting business, in-time summarizing existing knowledge has great application value also as it is easier to get on the spot and has very rich accumulation already. Also, all new knowledge discovered should be timely summarized into the specific body of knowledge. For mankind, this is really a great knowledge and cultural engineering that should be paid high attention to and also should be a social process which can be carried out only by crowd work because no one can do everything for this.

The digital twin approach proposed by us is really an ideal platform to support the crowd work that can be easily learned and applied by anybody who knows how to use the popular digital document tools (e.g. PPT) in writing or telling a story. To build a digital twin with the KGs is just like to organize the chapters and sections of an article. All needed to do is just concern about the main point to be stated and a collection of relevant supplementary materials. Each participant can quickly locate his contribution point by navigating the knowledge graph of a digital twin. Once seizing up whole context, based on his expertise and resource advantages, he

can speak his unique 'small story' to complement a more vivid 'large story'. The new contribution can be integrated into the system by a simple link without any complex interface issue. Even without any programming skills, all frontline knowledge and cultural workers, as long as they want, can engage in building their digital twin applications in the cloud.

David Weinberger expressed his unique view on the networked knowledge in following terms: "The Body of Knowledge" and "The Networking of Knowledge". Knowledge as a Body is an essential theme as elaborated throughout his book [6]. Knowledge is systematic and high interrelated, forming an organic collection. Only synthetic knowledge can create much higher value. On the contrary, unorganized and scattered ones would come down to the information level and are hard to embody the value of knowledge. Therefore, 'Knowledge as a Network' [11] is becoming a logical conclusion. The traditional system of knowledge "was constructed as a series of stopping points that worked well when knowledge was put down on paper." as said by David Weinberger in [12]. "Now knowledge lives on the hyperlinked Net, and links offer a never-ending invitation to go further, know more. What are the implications of a future in which human knowledge is no longer a finite compendium of scholarly works but rather a limitless, intricately connected network of people, ideas, and works?"

The digital twin approach makes these insights a true reality. Building digital twin is similar to a net-weaving work in the knowledge and cultural domain to gather scattered small piece of works into a large success to construct a new connected world for knowledge and cultural assets finally, towards the future Internet of Knowledge and Contents. The digital twin approach provides a common basis to organize available knowledge & contents, and absorb new knowledge & contents, that is also a big data topic, even a big resource, big content, big wisdom one either. Now the idea, method and support tools have all been there, the key is our further conscious action. Digital documentation tools will go back their starting point, becoming a natural mean in building digital twin for knowledge and culture. This would be a up-grade of original digital pressing, also a potential new business in the information economy.

6 FURTHER WORK

When running the digital simulation of a digital twin application on the PC environment, all related resource files can be stored into a common file directory and using their file name as respective superlink address. If the application is required to be migrated into the cloud and can be shared by various mobile users, the whole file directory is needed to be uploaded onto an available cloud disk and replace each superlink into their new IP address. It is just a routine work not difficult to study, anybody can do it manually even without knowing IT to directly deliver a cloud application. To promote such a process, we are also consulting with the platform supplier to provide an automated directory upload with all required address transformation, i.e. go cloud by one click.

If the application is carried out by a PPT tool, for the iPhone user, the PPT application can download by using its link and directly run it in the Keynote stage. For the other kinds of phones, we recommended to open and run it on the WPS platform which is available on almost all types of mobile terminals.

Once the digital twin application is becoming much more complex and bigger, it is unforced to decompose it into multiple ones with leveled calling, in other words, the superlink could be another PPT application to being called. It is without any problem in the PC environment because the Windows OS provides support for multiprocessing. However, while running on a mobile phone, an interrupt will occur as the underlying OS (e.g. Android) not have the multiprocessing capability. To solve such kind problem, it needs a strong technological support from the suppliers of digital document tools. Unfortunately, their current interests are concentrating on the Office application due to the market consideration. Therefore, we give a urgent appeal here to them to concern a new potential opportunity, i.e. to return their original intent in developing the digital document tools as a digital twin building tool in promoting digital transformation of knowledge and culture. Microsoft as an originator should re-examine what new contributions can make when taking a new perspective on digital twin building and blow the march bugle towards the mobile terminals. We will give more expectations to the Chinese provider Kingsoft, which have enough technical background in the mobile area, an appropriate solution proposal is possible even not touching any update in the underlying OS. For example, to support an automatic process switching when necessary. From a long-term

viewpoint for the digital twin application, it is also a must to have a close cooperation with the tool supplier. As for the underlying OS, the Huawei Harmony OS is undoubtedly a hopeful candidate as its built-in

multiprocessing capability, moreover, with its open-source orientation. In view of these, we dare to say: there is no insuperable barrier here.

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