Digital Twin Creativity Synthesis

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Contents

1 Introduction

A digital twin is the tool that has the capability to eliminate serious problems with the methodology to reduce unforeseen system problems [14]. It can also be described as a digital entity that is a fully synchronized replica of a physical entity. There has been a lot of interest regarding the digital twin in recent years. View Figure 1 bellow in regards to the popularity of the digital twin coined term by grieves back in 2002 [14].

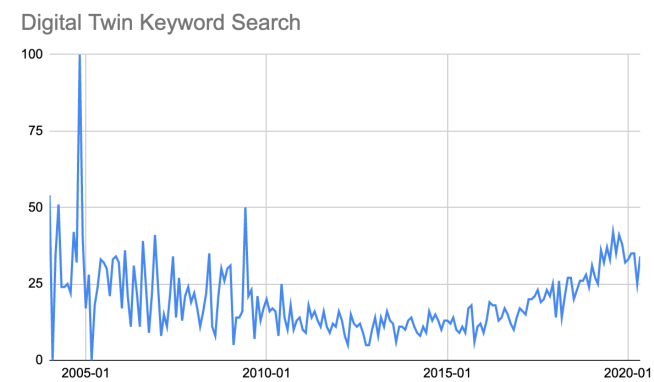

Figure 1: Keyword Digital Twin Popularity Through The Years

The purpose of digital twins is to understand the limitations and potential of the physical entity, That allows the largest potential of predicted benefits and minimizes unpredicted undesirable outcomes. This depends on each unique physical entity and the sensors in place to supply data to the digital entity.

Throughout the rest of this synthesis in section 2 the definition of a digital twin is explained more in depth. Going into the individual parts, use cases. In section 3 some sample implementations are presented which can be taken as a base blueprint for digital twins. In section 4 simulations are discussed in regards to digital twins and additions to the current simulation functionality is presented. In section 5 artificial creativity is explained and tied into the simulation functionality proposed in section 4. Then finally in section 6 further research is proposed and the synthesis ends with a conclusion in section 7.

2 Definition of a Digital Twin

Digital twins are a part of the new frontier of industry 4.0 which can be defined as the fourth revolution of industry. The digital twin can currently be used to identify fault diagnostics of physical entities through different means of implementation including deep transfer learning [23] among other things creating greater predicted benefits [18].

The definition of a digital twin is the automatic flow of data between a physical entity and digital entity. It is to be understood that the term digital twin is not simply a *digital model* which is defined as a manual flow of data from physical object to digital object. Nor is it a *digital shadow* which is defined as a manual flow of data from a digital to a physical object with a automatic flow of data from physical object to digital object. Creating a virtual mirror effect. A fully functional digital twin has high levels of fidelity that being a high degree of similarity between the physical entity and the digital one achieved through an automatic flow of data between digital and physical.
——figure here——-

2.1 Digital Entity

A digital entity is the digital representation of a physical entity. It receives all of its information from sensors, IoT, 5G, and other external tools see section 3.1 that monitor the Physical entity and communicate it back to the digital one. It is possible for the digital entity of a digital twin to have a digital model attached to it that is able to show a visual of what the physical entity looks like. This can also be shown in augmented reality for a 3D model if the designer so chooses [20].

2.2 Physical Entity

A physical entity can be described as the physical system. This for example can be a wind turbine, an engine, a factory floor, etc. Physical entities are monitored by sensors and other external tools (or if you rather linkage) to send back to the Digital entity. It is important to note that these external tools can be used for communication across both physical and digital. Unless within a purely digital simulation. View figure to see a mapping of digital and physical entities.
—-figure here—-

2.3 Use Cases

Anything physical has the potential to be developed into a digital twin. However, the main focus of digital twins currently rest within manufacturing and healthcare fields along with the potential of smart cities. "The International Data Corporation (IDC) forecasts that companies investing in digital twins will see improvements of 30 percent in cycle times of their critical processes in the next five years."[21].

In this section we start off by giving use cases that have already occurred in industry and then finish with potential uses of digital twins in the future.

Digital twins have been used to help improve optimizing productions on factory floors [16]. Help maintain complete control of whole buildings effectively reducing power usage[3]. Monitor engine performance through temperature sensors in wind turbines [5].

In the future digital twins have the potential among other things to monitor recycling and be able to see what physical parts can be reused for future models or products. 'Can enable a surgeon to see the impact on a patient's condition and the placement of electrodes in the heart before the surgery even begins' [4] and be able to think of creative solutions through simulations, view section 4.

3 Methods of Implementation

Use of digital twins on physical assets like wind turbines and manufacturing equipment already exist and are being used in industry [5]. A base blueprint or overall structure of digital twins has been presented to the research community and are described bellow.

The three-dimension model architecture for a digital twin is described as including a physical entity, digital entity, and a connection. This connection is characterized as the communication between physical and virtual [12]. The three-dimension model can be extended into a five-dimension model architecture.

With five-dimension, we have the physical asset, digital asset, Sensors, Digital Data Model, and the Connection Model. It is shown in A.Y.C Nee's paper on digital twin driven prognostics and health management for complex equipment that using the five-factor implementation improves accuracy and optimization due to how it is composed [22].

In regard to the five-dimension framework of a digital twin the sensors digital data model and connection model all have factors feeding into them. Both the three and five dimensions share the same inputs in regard to the digital entity which are: The geometry, physics, behavior, and rules.

The five-dimension framework can be described more complexly than it's three-dimension counterpart. In short there is a physical asset model(composed of one part), virtual equipment model(composed of four parts), services model(composed of five parts), digital twin data model(composed of five parts) and a connection model(composed of six parts) that integrates all four models together, view the table bellow.

—-add table—-

Using the five-dimension model within a wind turbine use case we see on average a 22 percent increase in identified faults in gearboxes compared to the original physical wind turbine method that does not access the wind turbine while predicting the fault cause and maintaining procedure. [22].

3.1 Current Tools

Corporations are also starting to offer solutions in the digital twin field for example Ansys, General Electric and Oracle, among others, have user customized digital twins that are providing advantages and optimizations in different fields and areas of industry [2],[7],[11].

3.2 High Fidelity or Not

(complete me) redefine fidelity here and why it is important to the overall digital twin. also explain how grieves spoke about the digital twin in his previous paper along with the current published survey. Implore how it is not really needed for a digital twin to have high fidelity and back it up with Arup industry paper that we read over before.

4 Simulation

A core aspect of a digital twin is its capability to preform simulations on its digital entity before making potentially expensive changes or the like to its physical counterpart. Digital twin high fidelity simulations can be seen today being used by National Aeronautics and Space Administration for flying spacecraft models as well as the U.S Air force [13].

'simulation optimization that can help us to find the best decision for the future; an analytics tool that can help us to learn based on the future simulated optimized data' [21].

Current capabilities of simulations are used for, handling discrete models, optimizing models or finding the best decision of each scenario, and finally learning decision making simulations based on future optimized data [21], [13]. With ultimately the base goal to be to help improve safety and productivity; limiting the non predicted issues. Comprehensive tools being used for digital twin simulations are GE Predix, Siemens MindSphere, and Ansys [19].

These technologies use data collection, data transmission, optimization services and deal with connections from the digital and physical world. Through use of machine learning analytics engines, big data is able to go from a cluttered mess to information that the system is able to handle and understand what to do with [1].

Additions can possibly be made to simulation capabilities by adding artificial creativity. To create simulations that are able to have the ability to think of new creative solutions based on the digital twins integrated sensors collected data. Artificial Creativity is defined in the next section.
//talk about unity040

5 Artificial Creativity

Artificial Intelligence is a computer science topic introduced to research in 1956, where the term was coined by John McCarthy (Smith). Artificial intelligence can be defined as intelligence demonstrated by computer systems that is able to complete tasks that normally require human level intelligence. Artificial Creativity is the ability for artificial intelligence to be able to produce innovative creative ideas, through means of manipulation of multiple dimensions of space from its understanding of the outside world. This can be done from making use of past information of the outside world and learn from it in order to produce new innovative ideas that have not been discovered before, i.e. creativity. In computer science researcher Dr. Boden has been researching since before 1997 about AI's ability to perform creativity [9]. She does this by first classifying what creativity actually is, view section 5.1. The field of artificial creativity parallels computational creativity in the figure x you can see the huge spike in popularity in both of the terms back in 2004 which then dropped and has remained steady in interest since 2009.

–figure here—

5.1 3 types of creativity

A core founder of this field of research is Margaret Boden. She defines three types of creativity. Those being combinations, exploratory, and transformative.

Creativity can be defined in three forms according to Boden [10]. Combinational, Exploratory, and Transformative. Combinational creativity can be described as taking familiar ideas that have already been show to the artificial system and then morphing it to generate novel ideas, "Examples include much poetic imagery, and also analogy-wherein the two newly associated ideas share some inherent conceptual structure"[9]. Interestingly, these familiar ideas are ranked based on relevance in an AI algorithm to help with the combinational creativity manipulation of surface level space. Exploratory creativity "involves the generation of novel ideas by the exploration of structured conceptual spaces. This often results in structures ("ideas") that are not only novel, but unexpected" [9]. You can imagine this in one form as the ant colony optimization algorithm [17]. That is, ants in an ant farm, going out into the world until they find food and report it back to the colony. Then once the information is received the other ants go and collect the food. Except with the food being ideas of a creative branch of thought and the ants being the machines synapses. Finally, transformative creativity is the AI's ability to take in past information from the outside environment and transform it by one or more dimensions of space that produces a new structure that could not have been foreseen before.
//I think for each type of creativity find a framework addressing it and then add more specific research of it

5.2 Combinatorial Creativity

//recent research in this area
//current executions and frameworks for this
//case studies

5.3 Execution Frameworks

Recent research on artificial creativity frameworks have been able to show new ways of generating exploratory and transformative creativity which often can overlap with each other [15]. In Jordanous paper on computational creativity they go into detail of how to produce a creative thinking framework that allows the machine to go through graphed execution processing to detail of how to produce a creative thinking framework that allows the machine to go through graphed execution process this process is mapped in figure x

—figure here—

5.4 Survey of Research

Artificial creativity is currently within a combinational and exploratory phase of research and case studies, –[6], [8] because its inability to fully comprehend the world around it. It does not know certain things so therefore most of the time its solutions to humans are nonsensical however, what if our artificial creativity framework had the ability to understand the full environment that it is dealing with. That being the potential for a digital twin to step in.

6 Further Research

Further research needs to happen within the field of digital twins simulations to see if it could be implemented for a digital twin to display artificial intelligence levels of creativity, which will become useful in discovering new innovative designs and solutions that current humans could not of thought of or did not have the time to experiment with.

Expansions in artificial creativity frameworks should also be investigated and expanded to include the frameworks of digital twins creating an all encompassing framework.

7 Conclusion

Throughout this paper we focused on digital twins, what they are, how they can be created and their benefits. After which we moved on to explain the simulation aspect of the digital twin and its current capabilities. It was then presented that the idea of artificial creativity can be used in parallel with the digital twins simulations in order to present new creative ideas and optimizations. It is stated that further research in this area is needed in order to produce a framework that is able to comprehend the outside world well enough for an AI to create solutions that produce the greatest gain and minimize the losses.

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