ML3 Whitepaper – The Digital Twins Written for Rootstrap, Inc.

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Introduction

Up this point, we have covered Machine Learning in two previous whitepapers. The first one examined the important concepts behind it, while the second one covered an application of it, which is known as "Deepfakes." This is essentially where both Artificial Intelligence (AI) and Machine Learning (ML) can be used to replicate a real, live human being. These faked images and videos look so real that it can be very difficult to discriminate against the real ones, even to a trained eye.

Specifically, the following topics were covered with regards to the Deepfakes:

1) The technical definition of it;
2) The algorithms that are used to create the Deepfakes which include:
    - Convolutional Neural Network;
    - The General Adversarial Network.
3) The subtle clues that you can use detect a Deepfake image or video;
4) The implications of Deepfakes.

The second of the last whitepaper also dealt with a concept called the "tinyML." While AI and ML algorithms are very efficient, they require an enormous amount of processing power in the beginning, when they are first learning. One of the reasons for this is that they require a huge amount of data in order to produce the desired outcomes.

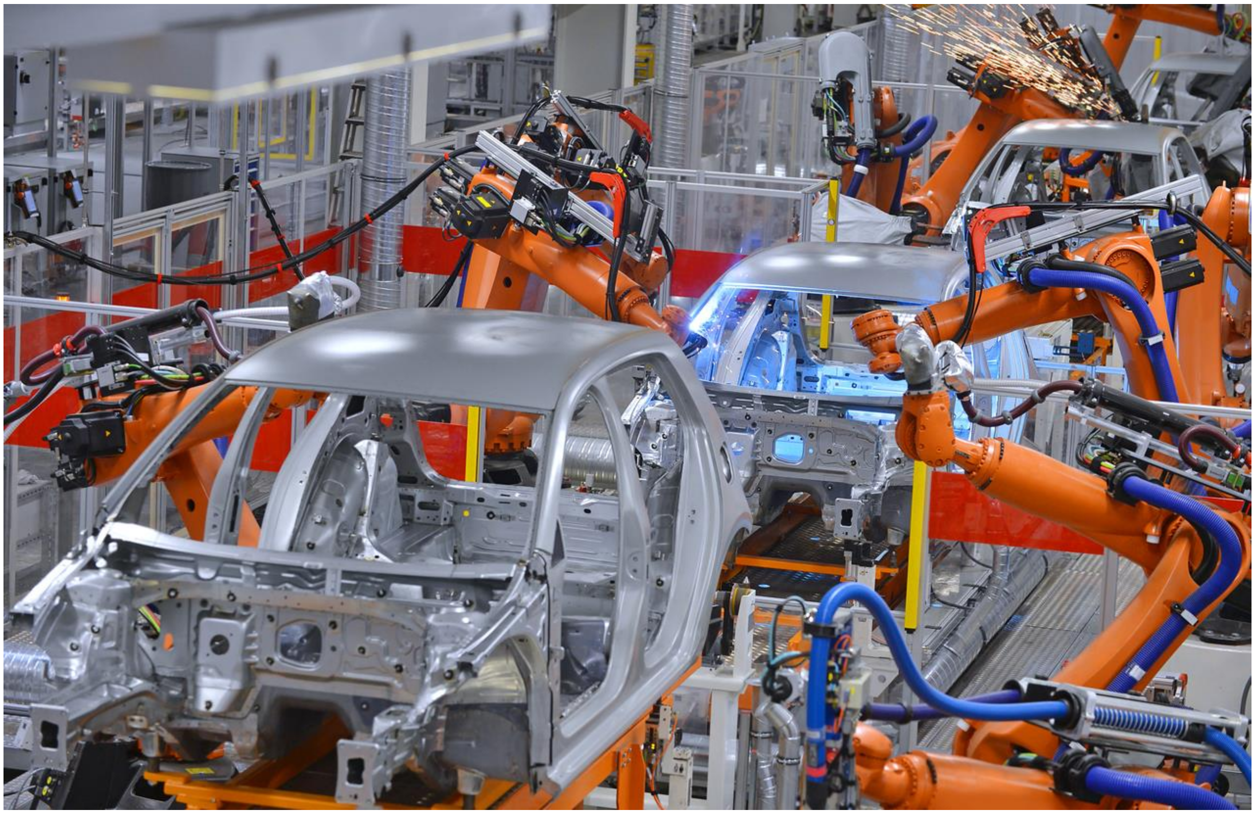
But the good news is that advances have been made so that a subset of the AI and ML algorithms can be taken and embedded onto much smaller forms of technology, where it might be needed the most. The following topics were covered as it related to tinyML

1) The Microcontroller;
2) The other technological components that are needed to support a tinyML environment;
3) The typical applications for tinyML;
4) The advantages and the disadvantages of tinyML.

This whitepaper will deal yet with another topic as it relate to ML- which is known as the Digital Twins.

What Is A Digital Twin?

Imagine walking into a huge manufacturing plant and seeing a lot of robotic machinery doing automated tasks. Probably one of the best examples of this is a car assembly plant. Here, you will see a lot of devices that look like arms doing a certain task on their own, powered by both AI and ML technology. This can involve everything from painting a door to screwing in plates at the bottom of the car. This is illustrated in the example below:



(SOURCE: 1).

While these machines can work indeed 24 X 7 X 365 on a real time basis, there are prone to wear and tear over long periods of time. But unfortunately, even with the best statistical modeling concepts available today, nobody can predict with accuracy when these machines could potentially break down. Meaning, there has been no real-world simulations of the many kinds of stresses that can be placed on these – it has been in theory only thus far. But that is until now.

With recent advances that have been made in Cloud based technologies such as with both the AWS and Microsoft Azure, Virtualization has now made it possible to replicate these robotic arms, and conduct real life tests to see where the breaking points could occur, and how to avoid them if at possible. In other words, you can create a Windows or Linux based Virtual Machine (VM) and create an exact replica of the physical arm.

This is also referred to as a "Digital Twin" – one robot exists in the virtual world via the VM, and the other robot exists physically at the car manufacturing plant. And it is not just testing can be done – both of these arms can be programmed to run together, in full synchronization. The technical definition for Digital Twins is as follows:

"A digital twin is a virtual model designed to accurately reflect a physical object. The object being studied — for example, a wind turbine — is outfitted with various sensors related to vital areas of functionality. These sensors produce data about different aspects of the physical object's performance, such as energy output, temperature, weather conditions and more. This data is then relayed to a processing system and applied to the digital copy.

Once informed with such data, the virtual model can be used to run simulations, study performance issues and generate possible improvements, all with the goal of generating valuable insights — which can then be applied back to the original physical object."

(SOURCE: 2).

You might be wondering at this point as to how an engineering staff at a car manufacturing facility would even know where to start working with the Digital Twin of a robotic arm. This is where once again AI and ML come into play. The virtualized robotic arm needs to learn first from its physical twin. Thus, the latter will consist of sensors and other types of input devices which can feed data to the robotic arm which resides in the VM, via the AI and ML interlinkages that are present between the two.

Once enough information and data have been fed into the virtualized version (and it will take a lot of it in order to learn first), it can then be used to simulate real world scenarios. Even mockups of the car parts for which the virtualized robotic arm will be used for can also be emulated, even from a three-dimensional point of view.

Digital Twins Versus Normal Simulations

A question that often gets asked at this point is why not use the technology of today to create another replicated copy of the robotic arm, which can be both physically seen and touched. A perfect example of this is the airplane cockpit simulator. There is first the original copy – which is the cockpit in the real plane that takes off and lands at real points of destination. Then there is just the cockpit simulator of this which resides somewhere else.

Although it mimics and replicates the real thing to the most minute detail possible (you can even pick a real example of an airport to take off and land at) you can perform only simulation at a time. Meaning, as you take off, you can only just emulate that and nothing else. Also, the physical simulator cannot learn anything from the real cockpit that is already in flight to create new environments for learning.

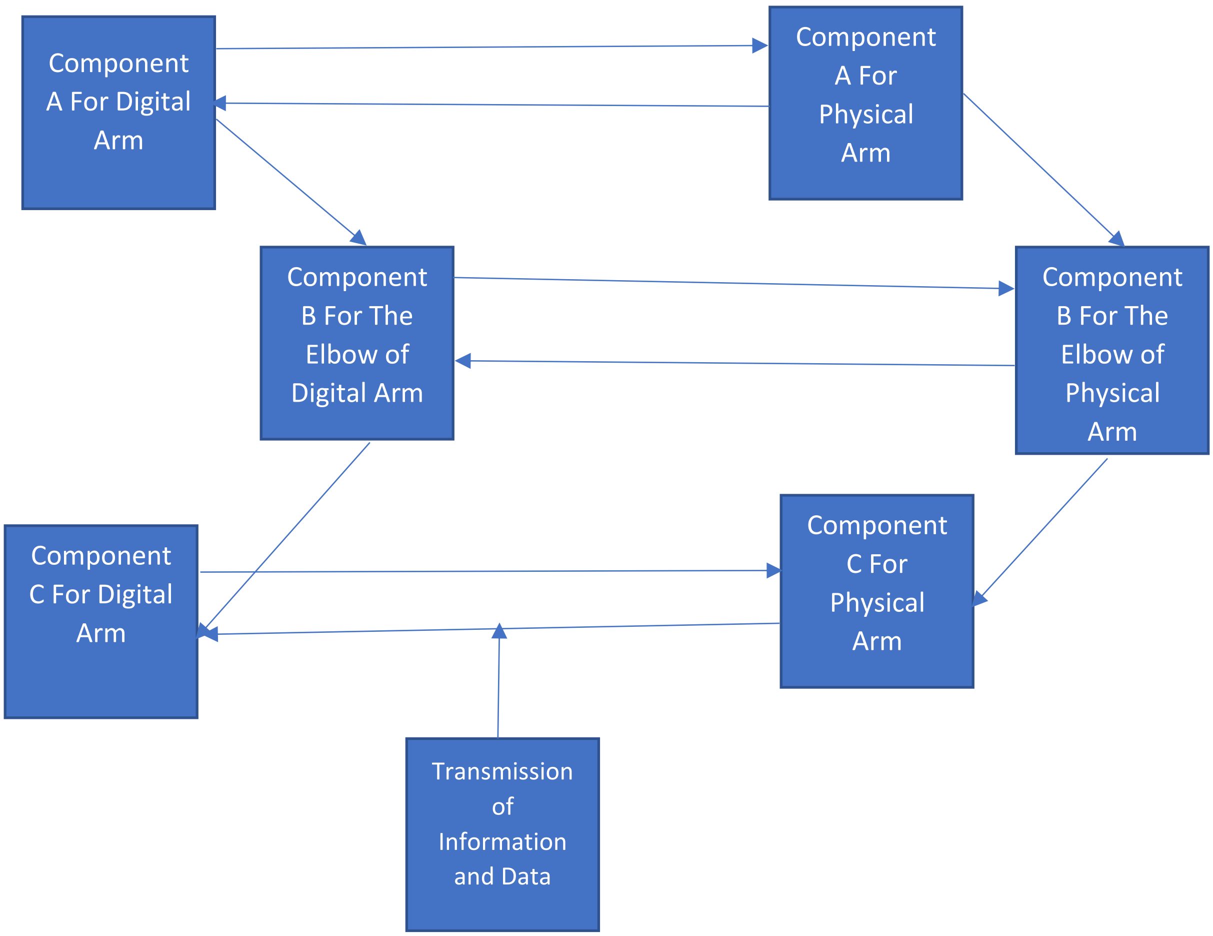
But with the Digital Twin, there are literally an infinite number of simulations that can be done at the same time. But better yet as stated before, information and data can be cross fed from both the physical and virtual environments. So, not only can the virtualized version of the robotic arm learn from the physical one, but the reverse can also happen where the physical arm also learns from the virtualized arm from the simulations that have been performed on it.

What Are The Various Kinds Of Digital Twins?

In the discussion the Digital Twins so far in this whitepaper, it has been assumed thus far that there is only one virtualized twin for every real-world robotic arm. In terms of mathematics, this represents a one to one, or 1:1 relationship. But since the Digital Twin is created and housed in a virtualized environment, now anything is possible. Here some the different combinations that can be created:

1) <u>The Component & Parts Twins</u>:

   This is deemed to be the simplest, or most basic construction of the Digital Twins. This can be viewed smallest of a functioning component. For example, only part of the Digital Twin relates to only part of the Digital Arm. But obviously there will be many components that are involved in the physical robotic arm, and as such will be replicated into the virtualized Digital Twin. Also, these are direct linkages, which means only one component gets just one linkage between the two. This is illustrated below:



It is important to note while the mappings are only on a 1:1 basis between the Virtualized and Physical Robotic Arms, there is an infinite amount of information and data that can be transmitted across the two, as indicated by the arrows going from the left to the right and vice versa.

2) <u>The Asset Twins</u>:

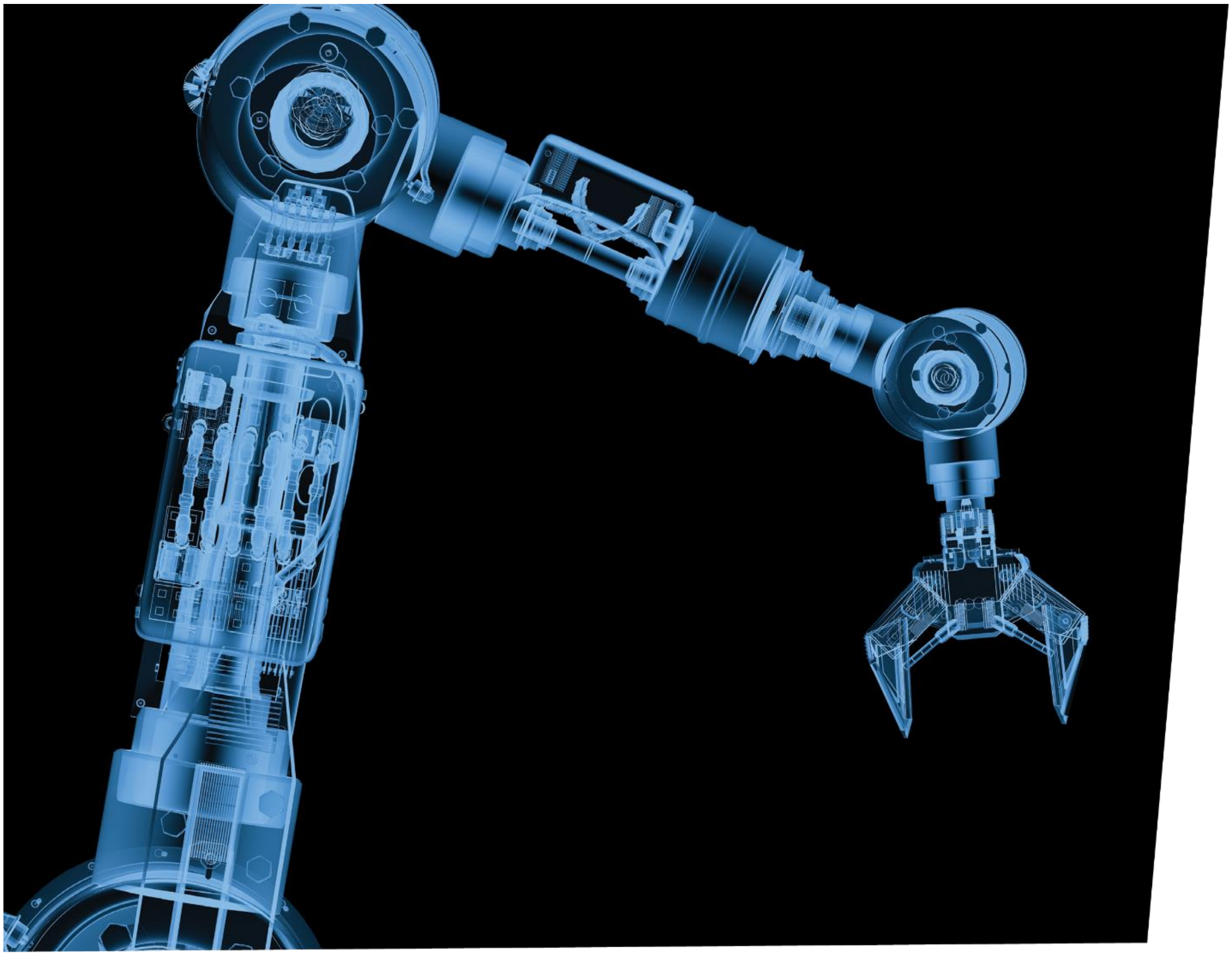
In this scenario, there are at least two components linked to each other between the Robotic Arms in both the Virtualized and Physical environments. So take the illustration from above, and multiply that by a factor of two. This will give you a good idea of how this category will look like. A real-world example of this can be seen below:

(SOURCE: 3).

This is the step where the Robotic Arm in the digital and physical worlds start to actually look like an arm, to varying degrees.

3) The System and/or Unit Twins:

This is the scenario where there are enough interlinkages between the components in both the Virtual and Physical environments in which an actual Robotic Arm is formed. This can be seen be seen below in the illustration:

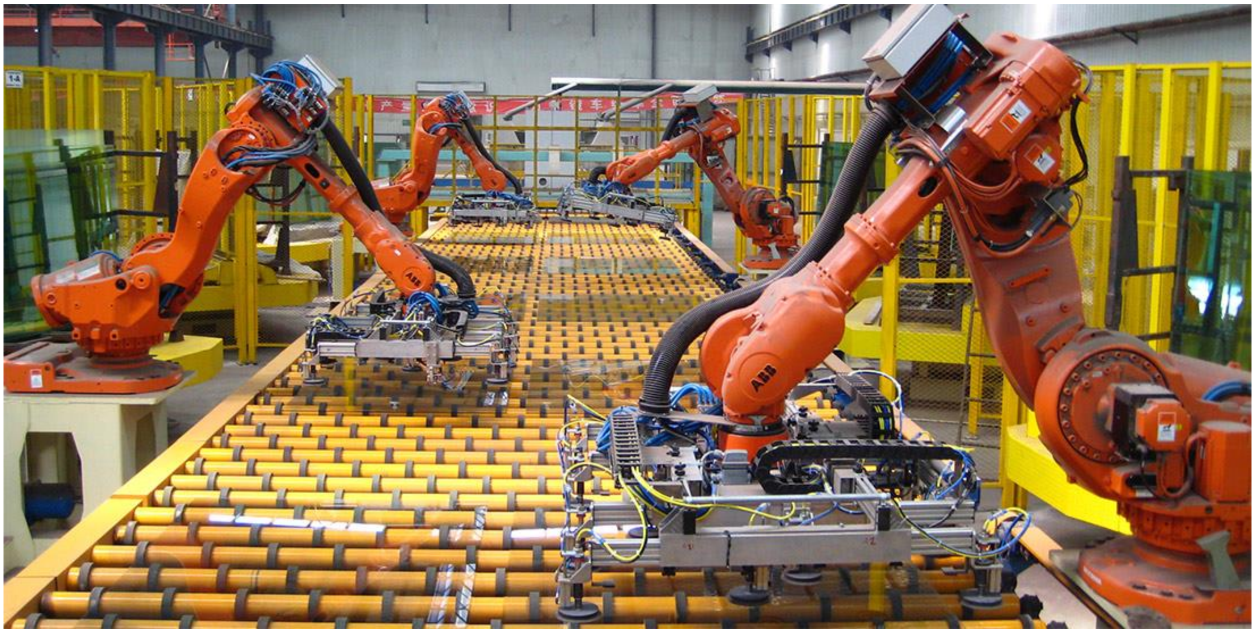


(SOURCE: 4).

It is at this step that you can see how all of the components work together, and feed information and data to one another in the Virtual and Physical worlds.

4) The Process Twins:

This is the condition where all of the robotic processes that are located in one area come together and form part of an entire production facility. This is illustrated below:



(SOURCE: 5).

At this particular level, the following questions can be answered, via the Digital Twin in the Virtual World:

*Are all of the synchronized components that are interlinked to one another working at its optimal performance levels?

*If there is a malfunction in one Robotic Arm, will that have a cascading effect on the others?

*Is the timing precise enough for the product to be completed exactly like the one before that in a rapid-fire succession?

The History Of The Digital Twins

The concept of the Digital Twins goes as far back as the early 1990's, just as the .com boom started to begin. The first, formal public introduction to it was made in a publication in the scientific journal known as the "Mirror Worlds." However, the concepts of the Digital Twins did not come into actual production until 2002, and in 2010, the name of "Digital Twins" was formally applied.

But the idea of using a virtualized replication of an actual, physical automated process came during the Apollo space missions to the moon, and NASA has been credited with this. For example, virtualized replicas of both the Command Module and the Lunar Excursion Model had to be created to see the impacts and hazards of outer space on these two spacecraft. From there, revisions were made to the engineering processes until a reliable and spacecraft could be built, and that was deemed to safe to land on the moon.

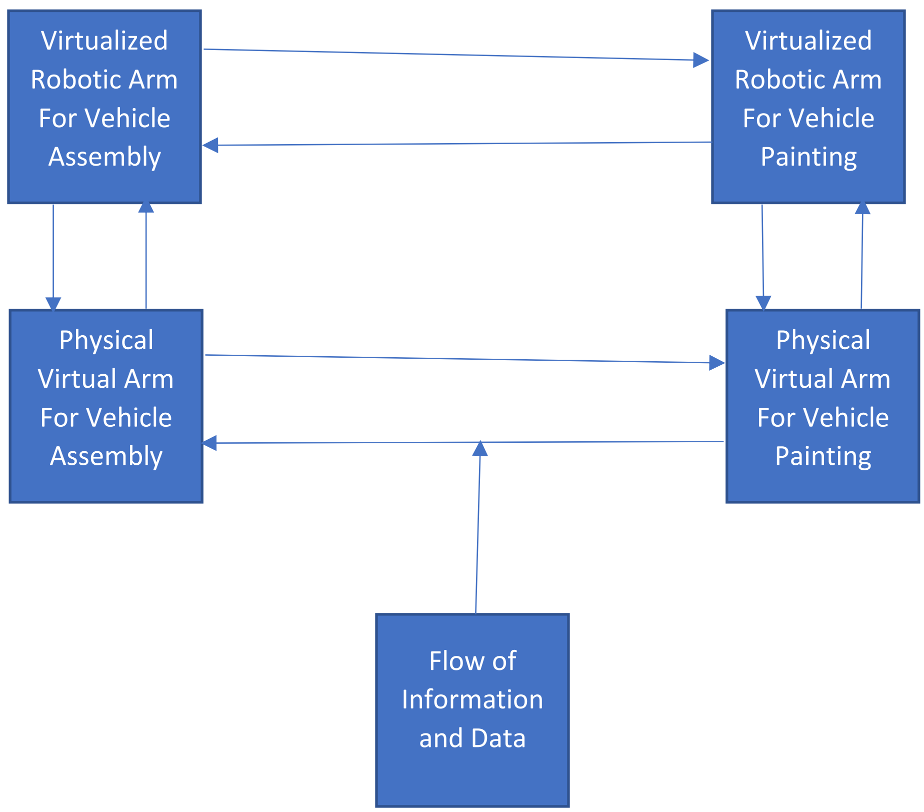
The Characteristics of The Digital Twins

Although the Digital Twins are almost pure replicas of one another (the Virtual and the Physical versions), they both have a number of key characteristics that are important to take note of. Some of these include the following:

1) <u>The ability to connect</u>:

One of the key characteristics of the Digital Twins is its ability to only connect to one another, but to other Digital Twins, whether they are in the Virtual or Physical realms. This is made possible by the IoT, or the Internet of Things. From here, information and data can be shared, and from here, new ideas for innovations for improving the overall efficiencies and quality control of the manufacturing facilities can be realized.

This can be seen in the diagram below:



In the above illustration, we can see the free flow of information and data from a car assembly Digital Twin to a car painting Digital Twin, and vice versa.

2) <u>The cleansing of the data sets</u>:

Before any information and data can be transmitted to the Virtualized Digital Twin, it must be converted into a digital format which can be understood and processed by it. In theory, it really does not matter where this "cleansing" takes place, but most of the time it happens at the level of Physical Digital Twin. Once this conversion has actually happened, the Virtualized Digital Twin can then contain and further process even larger amounts of information and data, which becomes known as "Big Data." From here, using the tools of both AI and ML, unhidden trends can be discovered and new extrapolations can be made which can then be used to create updated versions of any existing Digital Twins that are now being used in the production processes at the car assembly warehouse.

3) Inputs can be programmed:

In the beginning stages of the creation and deployment of the Virtualized Digital Twin, inputs have to be created so that the information and the data from the Physical Digital Twin can be fed into it. But over time, and as analyses into the Big Data sets continue, newer inputs can be programmed into the Virtualized and Physical Twins. From here, even newer robotic processes can be created which are far more efficient and productive.

4) Digital Traces:

One of the very unique characteristics of the Digital Twins is that they leave behind what are known as "Digital Traces." These can be compared to bits of latent evidence in the world of forensics. With enough of them, the crime scene can be rebuilt back up again to some degree or another. This same holds for the Digital Traces. If a breakdown occurs, say in the physical robotic arm, the Digital Traces that are transmitted to the virtualized robotic arm can then be used to further investigate as to why the breakdown occurred, and what processes can be improved upon so that this does not happen again in the future.

5) Modularity:

As it has been reviewed earlier in this whitepaper, the Digital Twins are built by using components. These components can also be viewed in a theoretical sense as "Modules," like in software source code development. In the Virtualized Digital Twin, along with the Digital Traces just described, the Modules can be broken apart for QA purposes, or to even create a newer type of robotic process.

Conclusions - The Benefits Of The Digital Twins

Although the concept of the Digital Twins seems like an upcoming technology, in a way it really has not been so. Unlike some of the other forms of technological advancements that are taking place, Corporate America as a whole seems to be fairly well receptive to it. This is based upon a recent survey that was conducted by PTC, which included over 300 business leaders representing a wide spectrum of industries:

*86% of them claimed that they have started or are at least very interested in mapping out a Digital Twin strategy.

*Only a mere .05% had no interest whatsoever.

(SOURCE: 6).

The usage of Digital Twins brings many benefits to a company, especially those that are involved in manufacturing and the supply chain and planning industries. Some of these include the following:

1) A new way to conduct market research:

Conducting live research often includes interviewing test subjects after they have tried a new product or service. Many times, if it were not satisfactory, it would mean having to start from the drawing board. But by using Digital Twins, any feedback received can be very quickly incorporated into the Virtualized Digital Twin. From here, a newer version of the product can be created, and tested in different kinds of environments, in order to make sure that all of the requirements have been met of the test subjects. Studies have also shown that customers will buy even more high-ticket items as long as they feel that their needs are being met on a constant basis. Using Digital Twins can definitely be a huge boon in this regard, because of the greatly reduced time to market.

2) Improved quality:

One key benefit of the Virtualized Digital Twin is that many different iterations of it can be created. This means that newer versions can be launched and even tested marketed in what is known as "The Metaverse." If good feedback is given, then this may just be enough to warrant a different version of an existing product. In other words, you can just simply create a better mousetrap that will receive greater amounts of attention for a mere fraction of the cost and time that it would take to develop in the real world.

3) Increased levels of supply chain and planning channels:

With newer products and services being produced on a much quicker basis thanks to the Digital Twins, trucks, cargo planes, and container ships can be more or less assured that their transportation lines will be fuller. This will be a huge catalyst in helping to stimulate global demand even more than before.

4) Productivity is increased:

Obviously, human beings are not machines, and there comes a point in time where we have to cease working for a period of time in order to get some rest. This is especially true in those kinds of situations where mundane, and ordinary tasks are done day in and day out, in a constant repetition. This eventually leads to pure burnout, with the employee leaving in search of greener pastures. But as new devices are created via the use of Digital Twins (such as the robotic arm), these kinds of tasks can be automated, thus leaving the employees to focus on what they do best in their job functions.

While this whitepaper has been designed to be much more theoretical in nature, our next one will look at real use cases of the Digital Twins.

Sources

1) https://www.automate.org/blogs/the-history-of-robotics-in-the-automotive-industry
2) https://www.ibm.com/topics/what-is-a-digital-twin
3) https://www.lanner.com/en-us/insights/blog/digital-twin-example-1-the-asset-digital-twin.html
4) https://www.microcontrollertips.com/developing-mixed-safety-critical-iiot-robotic-arm/
5) https://engineering.berkeley.edu/news/2017/01/berkeley-a-regional-center-in-new-robotics-manufacturing-consortium/
6) https://www.ptc.com/en/blogs/corporate/digital-twin-benefits
7) https://en.wikipedia.org/wiki/Digital_twin
8) https://www.ptc.com/en/resources/manufacturing/white-paper/state-of-digital-twin
9) https://www.ptc.com/en/blogs/corporate/digital-twin-benefits