Identifying a problem and solving it with a digital twin idea

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0. Learning goals

This advanced module aims to show the first steps of the design of a digital twin solution, which can be considered as the pre-design phase. It will be explained what is the main information to be set with the customer and/or the partner of the project. It is also pointed out that this process can also be used to present in short terms the digital twin module to people outside of the project.

Two examples will be shown where a digital twin solution had to be built from scratch. These two examples will show the importance of this pre-design phase: not doing it accurately may induce unexpected additional work during the design.

1. Introduction

More and more industries want to be part of what is called “industry 4.0” and one main concept that is increasingly present in that idea is the concept of digital twins. Digital twins allow us to reach different goal such as monitoring physical products, predicting a behaviour of a process, detecting abnormal phenomena, testing virtually a process, control remotely a machine and so on. It is the goal that determines the nature of the digital twin, so the whole creation process (choice of sensors, access to controls, etc.).

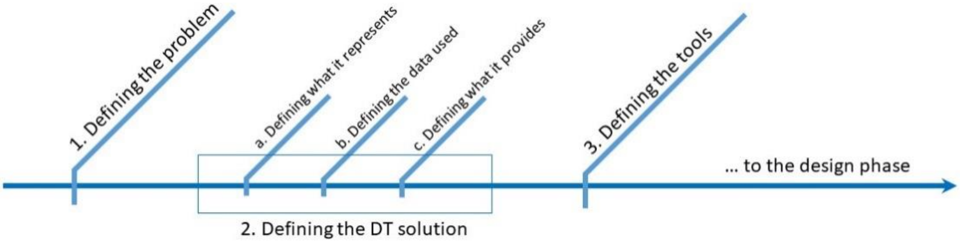
The purpose of this advanced module is to present the first steps of creation processes which can be considered as the pre-design phase. During this phase, the specifications of the digital twin are set with the working partners or the customers to define the desired solution clearly. The design phase following it varies greatly from one case to another; however, the definition process is common to any digital twin.

The process is mainly focusing on defining the principal aspects and properties of the digital twin that will be built later. It is a crucial step for two main reasons:

- Defining the principal aspects and properties of the digital twin will help to understand each other. It assures that all the working partners and customers understand the project.
- Defining the critical aspects such as the data sources before starting the design will prevent unexpected additional work.

A particular aspect of this module is that it mainly focuses on building a digital twin from an already existing physical object or entity. It is actually the most common case at present since digital twins and industry 4.0 are still relatively new concepts in the industry. Two different examples of design processes will be shown. These examples concern request of a digital twin from a manufacturing company and an airport. Both examples toggle different issues in vastly different environments and will show how diverse the digital twin concept can be.

As already mentioned, digital twins are still new even in scientific research, therefore there is no standard of methodology (at the time of writing of this module), and everyone uses its own. Therefore, it is presented here a general method which is based on recent scientific papers on that field and the experiences of practitioners.



The first steps of the creation process of a digital twin

2. Defining the problem

As for any project, it is important to define the problem that needs to be solved and its context. This point should be discussed with the customers to be sure of what are the purposes of the digital twin. This point is certainly more important for a project including a digital twin than any other because of the multiple existing definitions and interpretations of the digital twins. It is possible that each partner of the project has a different perspective on a digital twin solution, and it also means there may be a misunderstanding of what a digital twin is.

There are many varied reasons for a company to have a digital twin, but the two main ones are the amount of data and the access to information. Digital twins thrive on data; Therefore, digital twins are clearly the solution to problems for which a lot of data needs to be handled (the digital twin can be seen as a way to centralize data for instance). Also, digital twins will give access to information that would be difficult to obtain once the product is in use (if needed, the physical twin can be modified or updated with sensors that will give access to information).

It is also important to identify the context where the digital twin is required and will be the most useful. The context will certainly give a better understanding of the purposes and the possible interactions of the digital twin. It may also impose strict or specific technologies, protocols or procedures depending on the standards imposed (there are specific standards in pharmaceutical or food industries for instance).

3. Defining the digital twin solution

Once the needs for a digital twin are clearly defined (the problem to solve and its context), the first step is giving a definition of the digital twin to design. The definition of the future digital twin must precise its representation, the data it is based on and its contributions to the company (this definition can also be made simply by answering the three questions listed below). It is actually the most major step of the pre-design part: a clear definition of the requested digital twin will act as a reference during the whole project for everyone and will prevent unexpected problems, mistakes or misunderstanding during the design. A special attention is needed for the definition of data since digital twin is mainly based on data, thus it is often the main cause of problems during the design (as it will be shown through the examples later).

This definition of the digital twin solution must at least answer these three simple questions:

1. What does the digital twin represent?
2. What are the data used?
3. What does the digital twin provide?

3.a. What does the digital twin represent?

This part of the definition will help define the relationships of the digital twin with the physical and digital world. The digital twin does not necessary represent a physical object entirely because, depending on the problem, it can either be a machine, one of its mechanism or even the production line. It can also stand for complex physical structure, phenomenon, or interactions, such as a building or a flux of person.

One of the points of this question is the granularity level of the digital twin (the level of precision or the size of its representation). It is not necessary to have a digital twin the more detailed possible because it is probable that a part of the collected data or a part of the information provided by the digital twin will not be used. This can lead to a problem of data storage or waste of computer resources (which are both an economic and ecological problem). However, on the other side, insufficient data will lead to an incomplete or imprecise digital twin. This way of thinking is close to the “lean data”, which is opposed to the “big data” by selecting only the necessary amount of data.

All the physical elements which the digital twin interacts with (even the smaller one) must be listed because they will form together the cyber-physical system (either these physical entities give information, receive commands or both). It helps defining the interfaces of the digital twin with our physical world. This work must also be done in the digital world if the digital twin interacts with other machines or other digital twins. Its interfaces with other digital entities must also be defined.

By defining the interactions and interfaces in both worlds will help to define clearly what is represented by the digital twin. It is important for everyone working on the project but also for the future users.

This question may also help to choose the topology of the digital twin solution. If the digital twin only interacts with a physical entity, it might be interesting that the digital twin is embedded into the physical twin (topology called “embedded digital twin”). On the other side, if the digital twin represents physical interactions or multiple physical entities, it might be interesting for the digital twin to be an aggregate of different digital twins (topology called “aggregated digital twin”) or a unique digital twin with multiple connections to physical entities (topology called “multi-device digital twin”).

RAMI 4.0, linked to the industry 4.0, can help to in the future digital twin in its industrial environment. It gives a schematic view of the position that will take the digital twin and the possible interactions it has with other elements.

3.b. What are the data used?

The choice of the data is mainly based on what the digital twin represents. This representation is computed through models (a digital twin can be interpreted as a dynamic modelling of a physical entity). These models can be a 3D representation of the digital twin giving the geometries or positions of the elements for example, but it can also be a mathematical model used for detection, prediction, or simulation. Specific algorithms (such as machine learning or artificial intelligence) can make this model adapt to changes over the life of the system, which enables the ability to the digital twin to evolve with its physical twin (this ability is called “co-evolution” of the digital twin concept).

Data can be provided in many forms: commonly from sensors, which can either give binary (true or false) or numerical data, but also from simulation run outside or inside the digital twin, from analysis of documents, from interactions with other element of the cyber-physical system (for instance, communication between machines, other digital twins or even humans), etc. The form or the way to access the data can also be imposed by standards depending on the context. For example, the standards ISA 88 or ISA 95 are used in industry for the digitization of manufacturing processes but there is also the ISO 23247 standard which was published very recently. It described a framework that can be used as a methodology for the design and the implementation of a digital twin for manufacturing processes.

When the digital twin is built on an already existing physical twin, there may be already existing data sources. Analyzing the available data will help to see the possibilities of the digital twin. It is important to keep in mind that requesting more data could be troublesome because it may require modifications outside of the digital twin (either in the digital or physical world), thus it is better to work first with what is already available. On the other side, if the company stores more data than needed, it is interesting to add them to the digital twin to avoid cost due to an unnecessary storage and to make the twins more similar.

The properties of the data or the data sources are also important: the sampling frequency, the precision of the instruments, the noise ratio, etc. Some sensors will probably be chosen or developed during the design of the digital twin, but it is also possible that they are already available and placed on the system. In the last case, all the characteristics mentioned before are set, and the design of the data treatment is partially already constrained. How the digital twin received data and how it uses them may require more work in the digital twin design as the raw data may need to be processed in order to be used by the digital twin but also to be understandable by the people working with the digital twin (depending on how people will interact with it).

Since digital twins exist only from their data, it is essential that the flows are continuous, and these data are reliable at all times. If, in some scenarios, corruption or loss of data are possible, the digital twin requires methods to compensate. These methods can be mathematical models, from classic physical equations (e.g., solid or fluid dynamic equations or thermodynamics laws) to complex relations generated by the digital twin itself based on data analytics algorithms. They will be used to interpolate or extrapolate data to temporarily keep the digital twin in operation (however, this cannot work if problems persist or are too consequent) or to check if the data is corrupted (in addition to the use of filters), thus avoiding misinterpretations.

The number of sensors may also be limited due to a lack of space or in order to limit the disturbance caused. In this case, a model provided by mathematical methods with data from experiments or simulations is needed to extrapolate the requested data with a good accuracy. It happens also sometimes that sensors cannot be placed because it is difficult or impossible to measure directly or because they are not able to transfer data permanently (due to a harsh environment for instance). It is still possible to have a digital twin (so called "disconnected digital twin"): it will be correctly updated once the data are received but between these data packets it is based on models and interpretations. As an example, it is actually the case with production lines: the position of the parts is only known when they are scanned at specific points in the line.

Finally, the last source of data can come from data storage. Recorded data from previous runs can be imported or the digital twin can record temporary data or events (for its own use or for the records). It implies that a sufficient storage space must be anticipated, and data structures must be defined.

3.c. What does the digital twin provide?

The digital twin can provide any kind of information we want but it should be defined with the customer what is actually expected from it. In a way, this point follows the definition of the problem to solve explained previously. However, a part of this point is defining how the digital twin will interact with users, thus defining the interfaces between humans and the digital twin. It is essential to set how the information will be provided by the digital twin to the users but also how the user will give orders or requests to the digital twin.

The digital twin can be a simple digital shadow that will supply information, but in that case the feedback from user to digital twin is nearly nonexistent. However, it does not mean that the interface provided will be minimal. Sometimes it is interesting to have interfaces depending on who is the person using the digital twin: the ability level sets which information will be displayed. The information shown to the user must be understandable, which means that the data from the digital twin may need to be interpreted or transformed (i.e., the users do not need to understand the models or the algorithms, the digital twin can be seen as a box).

If it is expected to use the digital shadow to take action on the physical twin, it means that a feedback loop is added to the system, and it now becomes a digital twin (thus it is also called "decision loop"). This feedback loop can be executed by the humans or by the digital twin itself. In the first case, the feedback loop is considered as open since the digital world is not involved, whereas the loop is considered as closed if no human interaction is needed. Meanwhile, it is not mandatory to choose one: in fact, it is often a mix of the two depending on the risks of the desired actions (automatic or inoffensive actions can be executed by the digital twin, but dangerous decisions require user approval, for instance).

Setting the category at the first step of the design does not mean that the digital twin will remain in that category. Usually, when designing, digital twins often start with a digital model that is then increasingly more connected to the physical twin to gradually become a digital shadow and then a full digital twin. This also means that, for instance, an already existing digital shadow can become a full digital twin later on.

One of the greatest advantages of the digital twins is that it can be coupled with artificial intelligence or decision-making algorithms. Implementing those algorithms depends on the purposes of the digital twin. It can become a "control digital twin" if it is meant to make simple actions when required, or a "cognitive digital twin" if deep analysis and decision making are necessary, or a "collaborative digital twin" if the digital twin interacts with the users to seek advises or even to give advises.

4. Defining the required tools

Different tools and technologies can be used when creating a digital twin (whether for the development itself or for the daily use). The necessary means should be listed before the start of the design; this will help to plan the development of the digital twin, its installation, and help for future implementation or maintenance. Tools are used everywhere in the cyber-physical system enabling the digital twin to operate, either in the digital world (software, algorithms, interfaces, etc.) or in the physical world (hardware, networks, etc.).

Since industry 4.0 concepts are still relatively young and it is not easy sometimes for companies to take the plunge, it is necessary before starting any project to evaluate the “digital maturity” of the company or the customers. In a way, the digital maturity represents the level of ability of the company to accept the industry 4.0 concepts: it considers the technologies employed, the level of understanding of the concepts, the strategies determined to apply them, and the position of modern technologies in the company. A complete evaluation is not necessary but having an idea of the technologies available and the ability of the customer to open up to recent technologies will set the strategy of the implementation of the digital twin, thus its design and the tools used (for instance, using what is already available or choosing the most suitable software).

Sensors are already mentioned in the section on data processed by the digital twin, but all the hardware responsible for the connections between the sensors and the digital twin matters also. An essential element in digital twin technology is the internet of things (IoT or industrial internet of things IIoT) which helps for the realization of networks of sensors or actuators. IoT provides the possibility to have a part of the process partially realized locally before sending to the digital twin. This can be done by applying “edge computing” (processing already inside the sensors or data sources) or “fog computing” (processing inside gateways, between the data sources and the digital twin) but it may increase the hardware requirements.

Furthermore, the digital twin must be hosted somewhere: depending on the performances, its future interactions in the system and the security level required, the digital twin can be inside the physical twin, in a machine on the local network, or on a cloud computing system. It actually depends on topology chosen for the digital twin and that may fix the communication protocols. Moreover, standards may be involved in the choice of the technology depending on the context and the purposes because protocols or methods for data transfers may be imposed.

We often see digital twins represented by a 3D model of the physical twin but is certainly not mandatory. 3D representations can be necessary in the case where the human interaction requires one. Indeed, it is easier to understand the positions or the movements with a representation rather than numbers. It has also been proved that training is more efficient in a virtual reality environment. In contrast, the digital twin can be represented by a simple spreadsheet linked to its database when numbers or texts are clearly sufficient to have a view on the situation. If a 3D model is needed, the choice of the 3D modeller software depends on the available tools and the purpose of the digital twin. The software has unique features that can be interesting to exploit but can also be limited in terms of interactions. A comparative study should be carried out if the software is not already imposed by the customer or chosen on the basis of earlier experience.

The choice of the coding language could be important too. This depends on the operations that will be programmed, the interactions the developed script will have to handle in the digital twin and the available resources. The hardware may restrict the list of potential languages and it could be interesting to look at the frameworks that are available. There might also be some specificity for the management of the human-machine interfaces (HMI): the dashboard, the buttons or even the motion sensors in augmented reality must work efficiently because they are data sources.

In projects where the physical twin has already sensors placed; the definition of the data properties (explained in earlier section) might be imposed by the definition of the tools. It is also probable that, during the definition process of the tools, it appears that it is technologically impossible to reach the properties fixed previously with the data definition. These two situations show that iterations between the digital twin solution definition and the tools definition can happen during the pre-design phase but also during the design of the digital twin.

5. Keeping true to the digital twin concept

All the settings and definitions explained in the earlier sections are necessary before designing the digital twin. Once everything is set and clear, the design can start. The design highly depends on the kind of project and there are no real recipes. However, here are some guidelines and advises.

It is understandable that building progressively the digital twin makes its conception more efficient. In scientific literature, the digital twin conception is often described that way: at first it is a digital model which is a digital copy of the physical entity, then the communication from the physical world to the digital world is added to make the digital model become a digital shadow and finally the feedback loop is applied to have a complete digital twin. Later, functions can be added to the digital twin to give him controlling or thinking abilities (which makes the digital twin be called “control digital twin” or “cognitive digital twin” and even “collaborative digital twin” if deeper interactions with the users are added). Another method would be to build the digital twin with blocks of functions: the digital twin is built with first simple functionalities and progressively more complex functionalities are added to the system. The choice of the method probably depends on the capabilities of the design teams and the availability of resources, but in both cases the digital twin structure requires to be adaptive or evolutionary to accept changes easily.

The evolutionary aspect of the digital twin is also needed for its whole life. The physical twin will certainly change during its life; therefore, the digital twin must change as well. In the case there are modifications on the physical twin that should be transferred to the digital twin but cannot be handled automatically by the data transfer, it is interesting to have a digital twin that can be manually updated easily (for instance, if the support system of a machine has been modified, the CAD representation of that support system in the digital twin must be changed easily through the dedicated CAD software). However, it is essential to keep in mind that a digital twin can hardly be turned off or rebooted due to its multiple links and complex system, so the protocols for updates or failure recuperation must already be imagined during design.

All the definitions described before help to define goals for the design, but it does not mean that they will not change during the project. Actually, this will most certainly happen because of changes in the specifications, unexpected events or details not considered (mostly because the difficulties induced by those details were not expected). It could actually be interesting, when essential elements changes during the design, to do again this pre-design process to verify if any other elements must be adapted in consequence. Finally, even if they are presented in this module as part of the design, these definitions should stay with the digital twin and evolve with it as they are useful to present and characterize the project. This will certainly be useful years later when the digital twin needs an update.

The two next sections give examples of the design process of digital twin: one in manufacturing process and the other for airport management. It will be shown a summary of the definitions from the pre-design phase that has been explained in this module. You will see that using those definitions makes it easier to understand the digital twin. As already mentioned, not paying enough attention to the data sources during the pre-design phase can induce problems during the design. In both cases this kind of mistake was made, and it will be explained.

6. First example: manufacturing company

Manufacturing machines use tools to machine parts and unavoidably these tools wear off during the processes. The shape of the tool is changed thus the measurements of the produced parts change. The drift that appears between the measurements is small but must be corrected in time in order to avoid scraps. The common method to do so is to check the measurements of the last piece after a certain number of produced pieces: the measured gap is used for the correction sent to the machine (this kind of operation is called “tool wear monitoring”).

Definition of the problem:

The monitoring process is costly, both in time and money (if the part being inspected is out of tolerance, all the previous parts must be inspected as well and possibly scrapped). It would be particularly useful to have a way to automatically ensure the decent quality of the parts and to predict when a tool is too worn to meet the tolerances of the part or too worn that it presents a substantial risk of failure. However, directly measuring the shape of the tool to measure its wear is costly as well because it requires special equipment and stopping the manufacturing process for a period of time.

Definition of the digital twin solution:

Since it is difficult to directly measure the wear of the tool, the wear must be interpreted from other data. This should be done by creating a digital twin of the tool: from multiple data sources the state of the wear can be interpreted, but it implies the use of computation and data flows.

The wear is a parameter of the tool, and therefore of its digital twin as well. The analysis of the measurements of the produced parts will supply an “approximated wearing law” that helps to predict the wear (for instance, when turning an external diameter, the measurement of this diameter increases between parts). By analyzing these measurements, a drift can be computed through linear regression which would be the approximated wear law. This drift can then be used to anticipate corrections.

a) What does the digital twin represent?

Since the purpose of the digital twin is showing the wear of the tool, the digital twin must represent the tool. Through the digital twin we should have access to information such as the conditions of use and its wear. The digital twin should be linked to the machine that uses the physical tool to give the corrections determined but it does not need to be inside the machine. However, the measurements are taken outside of the machine with another machine.

The digital twin can be embedded to the machine using the tool, but a data flow is required from the measuring machine or the data base of the manufacture to the manufacturing machine. It can also be on a machine on the network of the manufacture, which also provides the availability to check the tool status from another machine such as a computer.

b) What are the data used?

The main source of data is the measurements from the parts produced by the machine. With these measurements, the drift due to the wear will be determined. These data can be acquired easily since the actual method for tool wear monitoring is already based on measurements from parts and in some production lines all parts are checked anyway. However, these data are provided after the part is produced so the corrections computed in the digital twin should be in advance and with a satisfactory level of confidence. Due to these particularities, this digital twin can be considered as a disconnected digital twin.

c) What does the digital twin provide?

The main purpose of the digital twin is to supply corrections based on the tool wear to reduce its impact on the produced parts. From the measurements the tendency linked to the wear is determined through linear regressions and this gives an approximated wear law. Based on this approximation, anticipatory corrections are computed and sent to the machine. This digital twin is aimed to be a control digital twin at first because this principle is mainly an auto-correction process, but adding models that will estimate the end of life of the tool and recommend a tool change makes it a collaborative digital twin.

Definition of the required tools:

There is no need for a 3D representation of the tool. It will not give more information or understanding. Furthermore, the information it handles gives an interpretation of the wear but not the actual shape of the tool. This digital twin will thus be mainly scripts for calculation. The programming language chosen for these scripts is Python. The main reason is that Python is open source and therefore free to use and there is a large community. Apart from this reason, there is no specific reason to use it instead of another language.

It could be interesting to visualize the effect of the correction using CAM software (CAM stands for “Computer Aided Manufacturing”; this type of software allows the simulation of manufacturing operations). By giving to the software the new approximated shape of the tool, it is possible to compute and simulate a new trajectory for the tool. The software NX CAM was chosen because the license was already available.

The hardware needed for the connection between the machines is not set for the moment. This will be under further investigation with potential customers when a first prototype of the digital twin is realized.

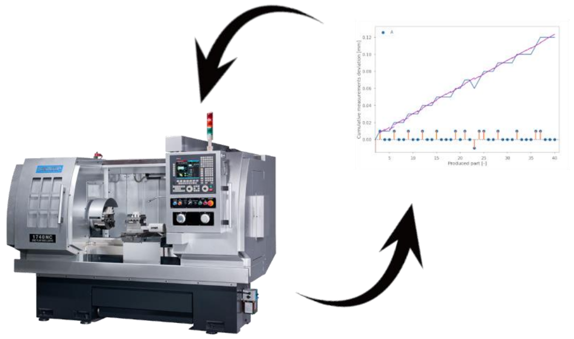
During the design:

At first, sample of measurements had to be taken to verify the type of data the digital twin will receive. At the same time, first drafts of the algorithm that computes the approximated wear law were made.

During the first tests, a detail neglected during the pre-design phase appeared to have an unexpected impact: the measuring instruments have a certain tolerance, and the measurements given to the digital twin are rounded in consequence. Therefore, the computed deviation varies suddenly between parts, and it induces errors in the computation of the approximated wear law (mainly for the first parts produced because of the low amount of data). Thus, it was decided to make the digital twin using data from a previous digital twin: if the manufacturing parameters (feed rate, lubricant, temperature, etc.) were similar to those of an earlier used tool, the wear computed should normally be close to the one computed by this previous digital twin. In other words, the present digital twin will use the records of an old digital twin as a model if the present computation seems unstable (induced by the low accuracy of the measurements).

This update induced that the first definition of the digital twin is no more correct, especially concerning the definition of the data used and the definition of the representation of the digital twin. To know which earlier digital twin has the closest manufacturing parameters to the present digital twin, all these parameters must be transmitted to the digital twins! Transmitting all the important manufacturing parameters induces a new definition of what the digital twin represents. For instance, the fact that a digital twin of a tool has the machine temperature as a parameter does not really make sense. Consequently, it was decided to create a digital twin of the machine to handle the manufacturing parameters, which will communicate with the digital twin of the tool.

The digital twin solution is thus now an aggregated digital twin with each digital twin representing a component of the manufacturing process of the part. This change is so important that the definition process must be started over again. The definitions of the data sources and the way to access them are completely new because a data storage is required, new sensors are needed and new interactions between the machine and the digital twin must be added.



7. Second example: airport

In an airport, many machines move on the tarmac: planes on taxiways, carts carrying luggage or cargo in dollies, bus carrying passengers, etc. For airlines, there are multiple operations to do before the plane takes off and after it lands. It requests a good organization with other companies and different vehicles (refuelling, catering, cleaning, loading and so on), which is usually not as easy as we might think. The project here is realized for a cargo airline to improve their management.

Definition of the problem:

With so many operations to handle, it can be difficult for the logistics services to keep track of their dollies all the time, especially in case of unforeseen events. In fact, at any time, the dollies can be anywhere, and it can take time to find them.

Hence, it would be interesting to have an application or software where the positions of all elements moving on the airport floor are continuously reported. Knowing all the positions will help the logistics services to handle more efficiently normal operations and to solve faster unexpected events.

Many different companies work in the airport, and they have their own vehicles as well. It could be interesting to know where the vehicles of the subcontractors for planning are, but getting the positions of the vehicles from the other companies would require specific agreements. It will also be difficult to find an agreement from airport control concerning the plane schedule for safety reasons.

Another point that would be interesting is the recording of positions during unforeseen events for later analysis. These analyses will help to find solutions or serve as support for training. A good add-on to this project will be to develop Key Performance Indicators (KPI) that will be used continuously.

Definition of the digital twin solution:

The interest for a digital twin is obvious. It is required here to have a digital copy of the positions of the dollies that is permanently updated. Operators will use a dashboard showing the positions to move them if required or to plan the next operations (making it an open-loop digital twin).

a) What does the digital twin represent?

The digital twin represents the positions of the vehicles of the company on the airport, and, if possible, the positions of the other elements they can interact with such as the airplanes and vehicles of other companies, especially the subcontractors. The users will see the digital twin as a dashboard with the positions on a map of the airport.

Each dolly will have on board a GPS beacon that will send its position at a certain interval of time. These positions will be collected and processed by the digital twin to be shown on the dashboard. The topology will then be closer to a “multi-device digital twin”: there is only one digital entity representing all the movements, but it will be based on multiple data sources, which are the GPS tags.

This dashboard should be accessible by multiple devices, such as the tablets given to operators to access the information anywhere in the airport. To do so, the dashboard will actually be a website.

b) What are the data used?

The main data sources are the GPS beacon placed on the vehicles. The beacons are already chosen by the IoT partner of this project; thus, the design of the digital twin will depend on it. Here are the properties: position is sent every 15min if the vehicle is moving, every 24h otherwise; collision and temperature sensors included; the battery life is estimated to be a few months from the average use of dollies. There will be tests executed during the design to check the accuracy of the system, but it seems already that the battery life can be troublesome.

The database of the company can be used as well to access the planning.

For the dashboard, the map will be constituted with web mapping platforms. Normally the maps of buildings will not change but the marking on the ground marking is seemingly changed sometimes.

As we mentioned, it could be interesting to have the position of the airplanes arriving to plan in advance the operations. For safety reasons, this information cannot be provided by air traffic controllers but there are plane tracking websites that may be other useful sources of data.

c) What does the digital twin provide?

Operators will access the dashboard with the Internet so they can access information anywhere in the airport through tablets, for example. This dashboard will show the map of the airport with the positions of the vehicles of the company and airplanes. The position of the dollies is continuously recorded so the user of the dashboard can access the position history if they wish. Once the KPI are determined they will be added to the dashboard to let the operators know the situation in real time.

A 3D model will also be provided with the digital twin to have VR set. This can help to visualize special event recorded for a better analysis, but it will help to train the staff too (it has been proved that learning is more efficient in a VR environment).

Definition of the required tools:

For the dashboard, a web mapping platform will be used to show the position of the dollies on the map. The map shown is the one from the web, but the positions of the dollies are put on through the API of the platform. This interface will be mainly programmed in JavaScript because it suits very well visual interface programming and there are API in this language. For the 3D representation of the airport (build manually from airport maps), the VR module will be built with Unity framework.

For the GPS tags, the protocol of communication is MQTT, and the network used is LTE-M. The connection to the network is provided with the SIM-card inside the beacon. A subscription to the telephone company providing the SIM-cards is compulsory to receive the MQTT messages from the sensors through the LTE-M network. Once MQTT messages are received they will be transcoded into exploitable data.

During the design:

During the design, the definitions were rewritten concerning the sensors. A first prototype of dashboard was programmed and works correctly. However, data collected are not correct and that is due to the sensors accuracy.

In fact, the accuracy of GPS technology depends on factors such as the position of the satellites that detect the beacon and the presence of metal in the vicinity of the beacon that can interfere with the calculation of the distance of the satellites. It actually gives an accuracy varying randomly from a few meters to a few hundred meters. This is not convenient for the digital twin because without references any location can be badly interpreted.

The mistake made here during the pre-design phase is not to have looked in detail at the precision of the sensors. This is partially due to the fact that they were imposed by a partner of the project. However, as it was detailed sooner, the most crucial step of the pre-design phase is to be sure of the data sources. Fortunately, there are solutions to that problem, such as finding more exact beacons or using differential GPS.

8. Conclusion

Digital twins give us access to a new way of seeing and processing data, and it is particularly interesting in cases where information is difficult to get, or information covers a large amount of data.

There are as many different digital twins as there are problems to tackle, but every digital twin project starts with the same questions. In this module was exposed a method for the pre-design of the digital twin, which can also be used a way to define the digital twin clearly. This method is based on three definitions: definition of the problem, definition of the digital twin solution and definition of the tools. It can help the partners and customers of the project to understand each other (since there are many different interpretations of what is a digital twin) and it can also help for later if another team needs to work on the digital twin. Defining completely and precisely will help to set the targets of the design and to identify potential future difficulties (for example, already define the topology thus determining the hardware and software that depend on it or build mathematical models to compensate in case of data loss).

As it was presented through the examples of the tool and the airport, the key step in this preliminary work is precisely identifying the collected data, which actually makes sense since the digital twins thrive on data. Imprecisely defining the data can lead to modifications in the data management system of the digital twin or even to a redefinition of the digital twin itself.

9. Bibliography

To go further:

* Recommended if you are interested in the methodology described.

** Recommended if you are interested in the typologies of the digital twins.

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