WP5: Data analysis, visualisation and feedback (Lead Cranfield, Dr John Ahmet Erkoyuncu)

Dr Dedy Ariansyah
Research Fellow in AR for Through-life Engineering

05/02/2020

Objectives

- To show the example of the basic Digital Twin (DT) system on the condition monitoring and key components involved in building DT system for gearbox machine demonstrator
- To show how DT system is built through a step by step procedure

Demo #1
DT Helicopter computer system

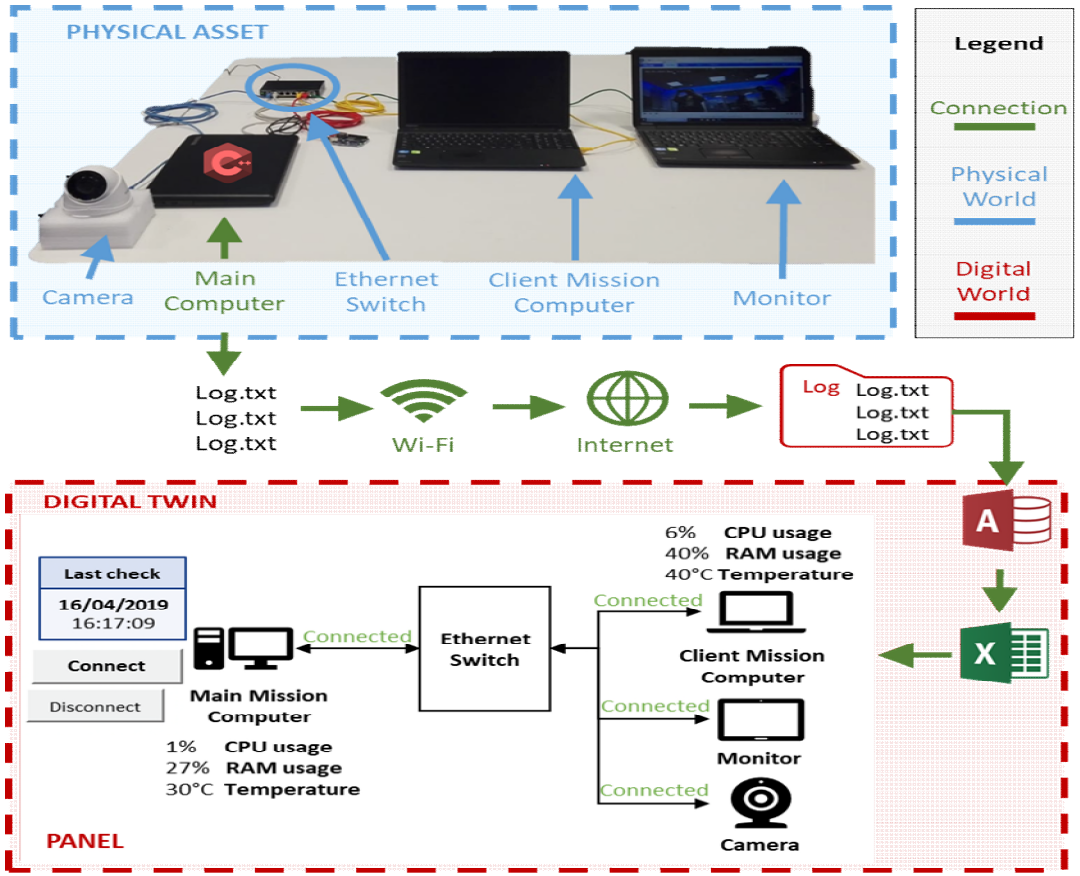


Fig. 1: DT system architecture for condition monitoring of computer system in helicopter

Demo #2
Gearbox machine

Developing a second demo of Digital twin for a gearbox machine demonstrator

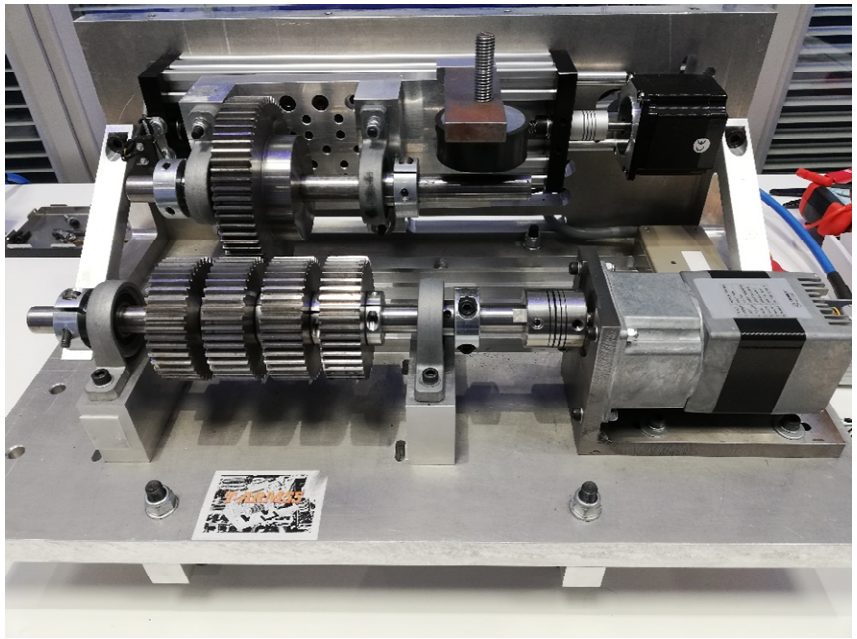


Fig. 2: Gearbox machine

System architecture of DT gearbox

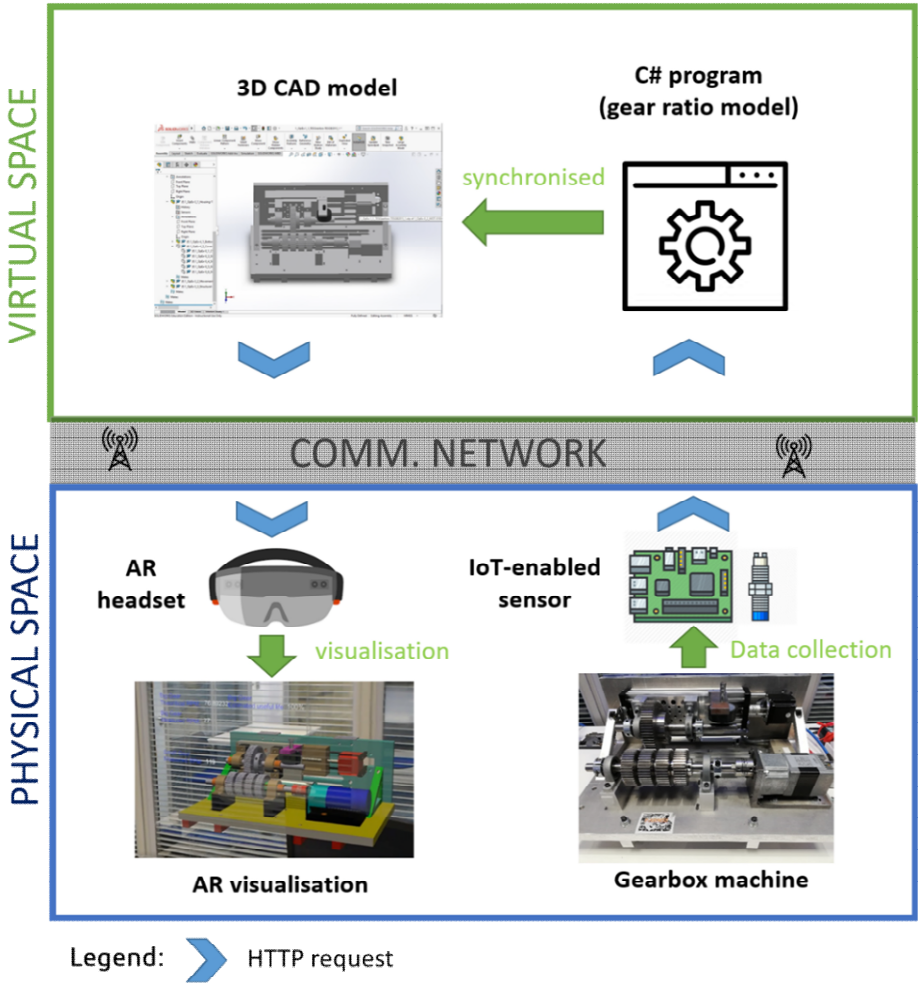


Fig. 3: System Architecture of DT Gearbox

How is the Digital twin is built?

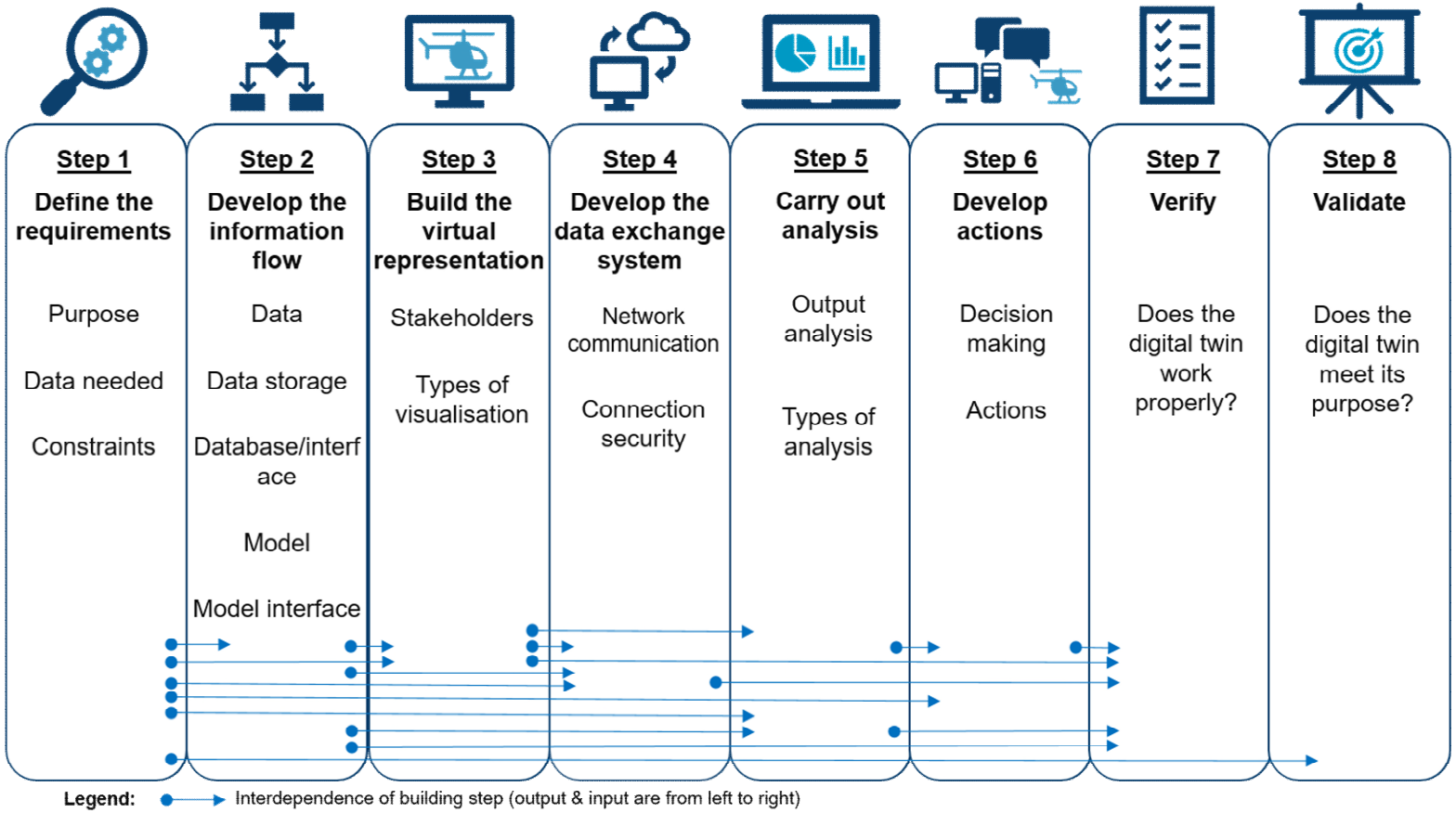


Fig. 4: Building steps of the digital twin

Design elements of DT system

Physical world

- **Equipment/Actuator** (perform functions)
- **Sensor** (detect physical parameter)
- **Controller** (transmit control commands)
- **Device for networking** (antenna, transmitter, receiver)
- **Visualisation device** (desktop, VR/AR/XR devices)

Digital world

- **Source code** of software
- **Data repositories** (database)
- **Data management** (RDBMS, Ontology)
- **Digital model** (CAD models, schematic, CAE models, numerical models, statistic models, etc.)
- **Intelligence** (machine learning, deep learning, data analytics)

Connection

- **Network, connectivity IT, security**

Step 1. Define the requirements

- The aim of DT
  - What is the expected outcome?
    - ✓To monitor the operation of the gearbox and to plan the right maintenance task
  - What is the expected improvement?
    - ✓Downtime reduced -> availability increased
- What data are needed?
  - ✓Gear performance data
- Constraints?
  - ✓Lack of sensor data and material degradation model

Physical world

- **Equipment/Actuator** (gearbox)
- **Sensor** (?)
- **Controller** (?)
- **Device for networking** (?)
- **Visualisation device** (?)

Digital world

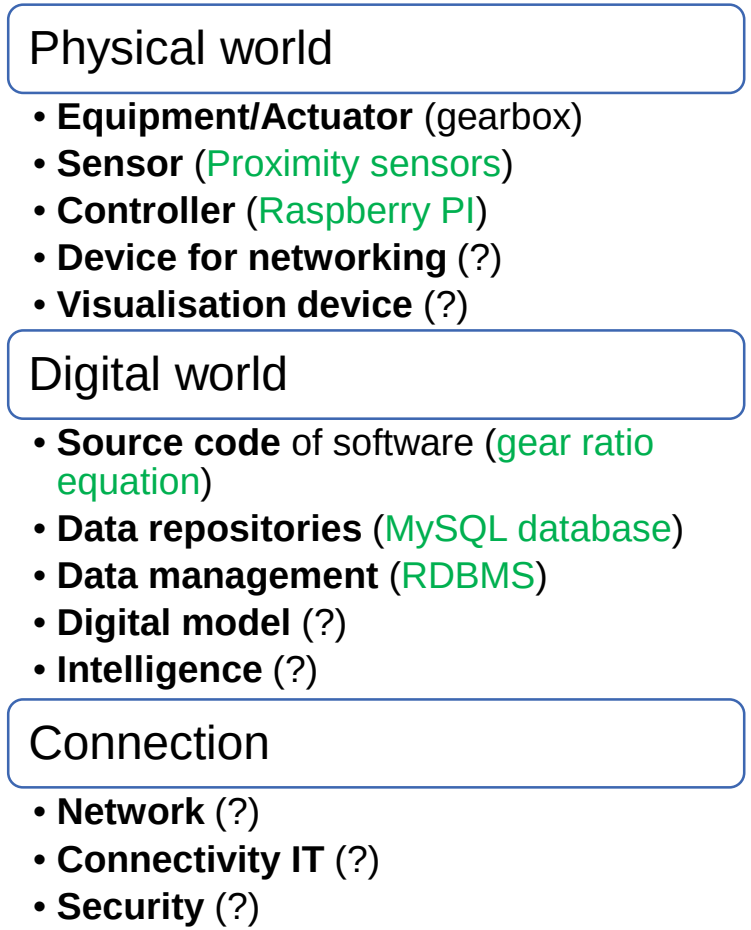
- **Source code** of software (?)
- **Data repositories** (?)
- **Data management** (?)
- **Digital model** (?)
- **Intelligence** (?)

Connection

- **Network** (?)
- **Connectivity IT** (?)
- **Security** (?)

Step 2. Develop the information flow

- What are the data sources?
  - ✓ Proximity sensors, encoder, piezoelectric, data from controller (Raspberry PI, PLC controller), source code of software, user input, etc.
- What type of data storage to use?
  - ✓ SQL database, non-SQL database, SPARQL database
- What data management to use?
  - ✓ RDBMS, Ontology



Step 3. Build the virtual representation

- How the DT is visually represented?
  - ✓ Desktop-based 2D, Virtual Reality, Augmented Reality, Mixed-reality
  - ✓ 3D CAD model of physical asset is needed

Physical world

- **Equipment/Actuator** (gearbox)
- **Sensor** (Proximity sensors)
- **Controller** (Arduino)
- **Device for networking** (?)
- **Visualisation device** (AR headset)

Digital world

- **Source code** of software (gear equation)
- **Data repositories** (MySQL database)
- **Data management** (RDBMS)
- **Digital model** (CAD model)
- **Intelligence** (N/A)

Connection

- **Network** (?)
- **Connectivity IT** (?)
- **Security** (?)

Step 4. Develop data exchange system

- How large is the network coverage area?
  - ✓ Personal Area Network (e.g. Bluetooth)
  - ✓ Local Area Network (e.g. Router)
  - ✓ Wide Area Network (e.g. Modem)
- What is the connection protocol?
  - ✓TCP
  - ✓UDP
- What are the measures for network security
  - ✓WPA2, Firewall, Mac authentication

Physical world

- **Equipment/Actuator** (gearbox)
- **Sensor** (Proximity sensors)
- **Controller** (Arduino, Raspberry PI)
- **Device for networking** (Router)
- **Visualisation device** (AR headset)

Digital world

- **Source code** of software (gear equation)
- **Data repositories** (MySQL database)
- **Data management** (RDBMS)
- **Digital model** (CAD model)
- **Intelligence** (N/A)

Connection

- **Network** (LAN and WAN)
- **Connectivity IT** (TCP/IP)
- **Security** (WPA2, Firewall, MAC authentication)

Step 5. Carry out analysis

- What are the desired insight(s) from the DT?
  - ✓ The sign of gear degradation (e.g. abnormal rotation speed)
- What type of data analysis needed?
  - ✓ Statistical analysis; comparing current and normal operating condition
- What tools used to perform analysis?
  - ✓ Statistical analysis tool/API

Physical world

- **Equipment/Actuator** (gearbox)
- **Sensor** (Proximity sensors)
- **Controller** (Arduino, Raspberry PI)
- **Device for networking** (Modem and Router)
- **Visualisation device** (AR headset)

Digital world

- **Source code** of software (gear equation)
- **Data repositories** (MySQL database)
- **Data management** (RDBMS)
- **Digital model** (CAD model)
- **Intelligence** (N/A)

Connection

- **Network** (LAN and WAN)
- **Connectivity IT** (TCP/IP)
- **Security** (WPA2, Firewall, MAC authentication)

Step 6. Develop actions

- Define condition-action rules
  - ✓ Reduce the demand on the current asset and distribute it to the standby asset
  - ✓ Initiate maintenance schedule on the current asset
  - ✓ Shut down the operation of the asset

- Mechanism of action
  - ✓Reduce the demand by manual control
  - ✓Initiate maintenance schedule by manual request of work order
  - ✓Shut down the asset by manual control

Physical world

- **Equipment/Actuator** (gearbox)
- **Sensor** (Proximity sensors)
- **Controller** (Arduino, Raspberry PI)
- **Device for networking** (Modem and Router)
- **Visualisation device** (AR headset)

Digital world

- **Source code** of software (gear equation)
- **Data repositories** (MySQL database)
- **Data management** (RDBMS)
- **Digital model** (CAD model)
- **Intelligence** (N/A)

Connection

- **Network** (LAN and WAN)
- **Connectivity IT** (TCP/IP)
- **Security** (WPA2, Firewall, MAC authentication)

Step 7. Verify

- Physical asset
  - ✓ Check if physical asset is running properly
- DT data and models
  - ✓ Check if sensors are properly installed
  - ✓ Check if right data are measured
  - ✓ Check if all desirable data are stored properly
  - ✓ Check if the gear ration model can process the data and produce the same output as its real twin
- Data reading
  - ✓ Check if DT read the right data from database
- Data processing
  - ✓ Check if the right data are fed into the right program/source code
  - ✓ Check if there is a bug in the source code
- Data visualisation
  - ✓ Check if the the status and behaviour of displayed DT reflects its physical twin
  - ✓ Check if the DT read the right data from the database
- Data exchange
  - ✓ Check if the speed of the updating rate acceptable
- Desired insight
  - ✓ Is the information relevant and easy to understand?
- Develop action
  - ✓ Check if the operator can recognise the known situation from the DT and take a proper action

Physical world

- **Equipment/Actuator** (gearbox)
- **Sensor** (Proximity sensors)
- **Controller** (Arduino, Raspberry PI)
- **Device for networking** (Modem and Router)
- **Visualisation device** (AR headset)

Digital world

- **Source code** of software (gear equation)
- **Data repositories** (MySQL database)
- **Data management** (RDBMS)
- **Digital model** (CAD model)
- **Intelligence** (N/A)

Connection

- **Network** (LAN and WAN)
- **Connectivity IT** (TCP/IP)
- **Security** (WPA2, Firewall, MAC authentication)

Step 8. VALIDATE

- Validate the capability of the DT system to monitor the degradation of gears before failure occurs
  - ✓ Conduct an experiment to test whether a user can recognise the early indication of gear deterioration with and without DT
- Validate the capability of the DT system to improve the availability of the gearbox machine
  - ✓ Conduct a periodic inspection to assess whether condition-action rule informed by DT improve the availability of the asset in comparison with the non-DT system