Smart Industry workshop on
Data driven business and cyber security at the factory floor

SMART INDUSTRY (Fourth IR/I40 in NL) DUTCH INDUSTRY FIT FOR THE FUTURE

www.smartindustry.nl

Egbert-Jan.Sol@TNO.nl may 2019

A TNO initiative made possible by a subsidy of the Dutch Min. of Economic Affaires & Climate

Program

09.30-10.00	Intro with data collection & cyber security on the factory floor and from equipment shop floor example and training course equivalent with Raspberry Pi
10.00-10.30	Assignment 1 – Get remote access to your Pi from own notebook and try Python
10.45-11.30	Data Driven Business trends and key issues (legal, standards, cyber security, ..) - evolution towards open systems (IEC-61131, IETF IP/TCP, Unix/C/Python) - data monitoring & visualization, Digital Twinning, Augmented Reality - from hardwiring (PLC) to visual programming & training of AI/Machine learning - legal issues (of machine/IoT data collection and sharing) - international standards: OPC-UA, Ethernet, TCP/IP, Admin shell
11.30-12.15	Assignment 2 – Collect I/O data from a Pi to your own computer using OPC
13.00-13.45	Cyber security - Explanation of IP/Ethernet networks and how to make them secure
13.45-14.30	Assignment 3 – Collect I/O data from an industrial PLC (RevPi+revpimodio)
15.00-15.30	Data Collection with MQTT
15.30-16.00	Assignment 4 - Secure configuration of for data collecting from Pi and Industrial PLC
16.00-end	You have worked with open source tools to collect data from shop floor & equipment, and understand how to configure and use them in a cyber secure way.

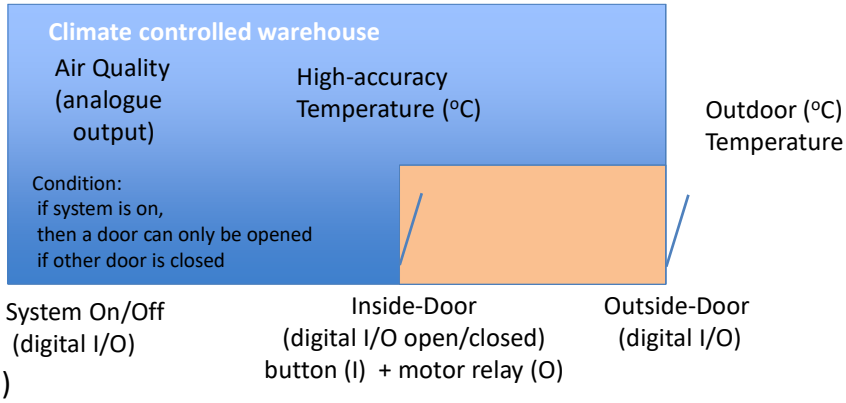
SMART INDUSTRY DUTCH INDUSTRY FIT FOR THE FUTURE

Securing a data driven Climate controlled warehouse:

business case for a data driven system:

cost saving: minimizing energy loss due to open doors
+added value: traceability for customer – quality guarantee
but also protect against a (hostage/bitcoin) hacker

Collect (24/7) data
1st goal:
data visualization,
2nd goal:
monitoring, e.g
on energy loss/temp. var.
3rd goal:
optimal control (using lot of data for training AI algo.)



Example: Raspberry Pi + Freeware Software

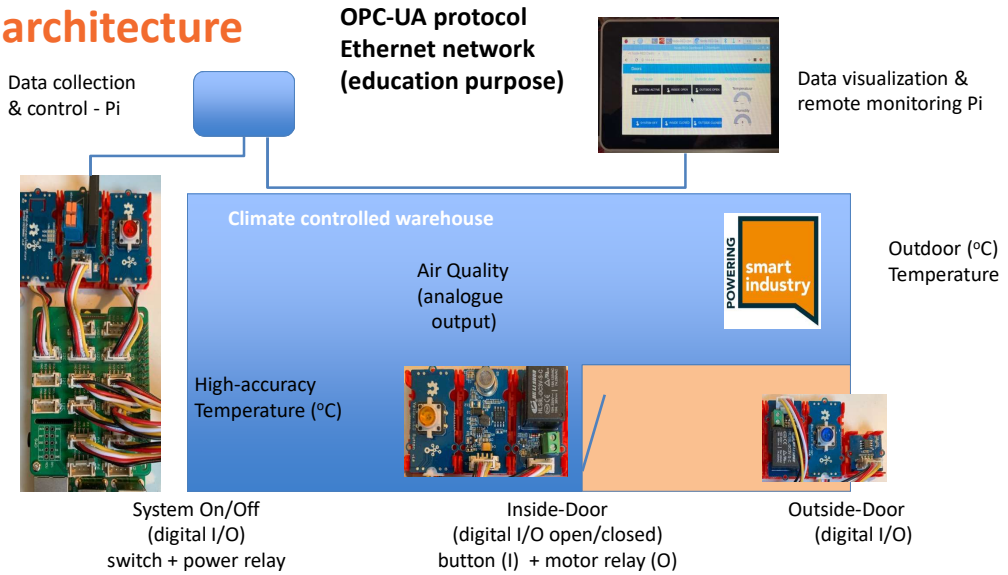
Monitoring the energy consumption on a smart e-meter in the warehouse (but also at your home (elec., gas, etc.)

Slimme Meter Do-moticz Starter Kit met Raspberry Pi 3B+

€ 80,99

Egbert-jan.sol@tno.nl

Demo architecture



Proprietary versus open source systems

(fieldbusses vs IP or closed/proprietary vs open source software (Unix-alike))

Discussion: what to do, what is more cost effective in the long run, what is more secure?

Profibus, Modbus, Foundation Fieldbus, MODBUS, CAN, Bitbus, Sercos, Interbus, HART, ..
EtherCAT, Powerlink, DeviceNet, .. all their variants and each with its own protocol
versus
Ethernet/IP/TCP with on top of TCP their own protocols as HTTP/HTML, MQTT, OPC-UA

1985-2015 from vendor lock-in and incompatible between systems
to today interoperable with Ethernet/IP/TCP/OPC-UA similar to www with Internet/HTML

Proprietary or closed systems as with their own, often costly hardware & applications
versus
Open source systems as Unix and its many variants as Linux, Ubuntu, Debian/Raspbian
using well-known and proven languages as C & Python running on all kind of hardware

Workshop: vendor independent, focus on open systems as many concept apply to proprietary systems too.

Egbert-jan.sol@tno.nl

Open source PLC: e.g. Kunbus Revolution Pi (RevPi)

PLC ala Siemens, Beckhoff, etc versus Open source PLC

e.g. RevPi as open source PLC
Hardware (Core 3)
- 64bit, 4 Core BCM2837 processor on 1.2Ghz with 1GB SDRAM
- 4-port USB, Ethernet, ~~Wifi/Bt~~, HDMI, running on 5V/2.5A

Software
- Raspbian (=Debian Unix + BCM2837 patches)
- Revolution Raspbian (=Jessie with an Realtime patch (no Wifi, no Bt)
- on ~~a 8GB microSD card~~ on 4GB eMMC compute module

Info at www.revolution.kunbus.com , video's and
- open source software from www.revpimodio.org

IEC 61131-3 PLC programming software,
- but also Python or C event-driven programming

- Unix/Open source security (via Ethernet, no Wifi or Bt!!!)

microSD cards are not reliable after 1 year intensive R/W use
Industrial Pi's use compute modules with eMMC

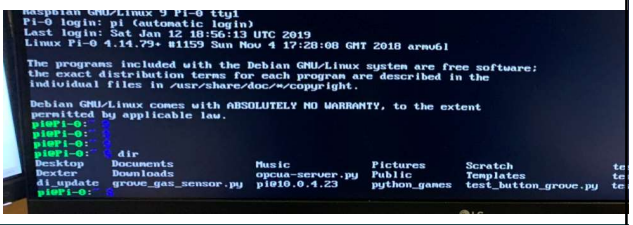
Raspberry Pi, or short Pi

Hardware
- 64bit, 4 Core BCM2837/Cortex processor on 1.4Ghz with 1GB SDRAM
- 4-port USB, Ethernet, Wifi/Bt, HDMI, running on 5V/2.5A

Software
- Raspbian (Debian Unix) on a 8GB microSD card

Info at www.raspberry.org, google search and youtube video
- e.g learn.adafruit.com/ lesson 1 and further

Standalone system: Keyboard, HDMI monitor
- usb mouse (in case of window interface)
- login : pi,
- password : raspberry
- commant prompt = pi@name:~$
  - example commands
- pi@Pi-0:~$ sudo raspi-config
- pi@Pi-0:~$ startx



Egbert-jan.sol@tno.nl

Preparation instruction for participants or available on USB stick

If your company allows you to install programs on your notebook, prepare yourself with

PuTTY (only for MS-windows), VNC-viewer and Python (all freeware/open source) from
https://www.putty.org
https://www.realvnc.com/download/viewer/
Assignment 3: optional MQTT.fx (from mqttfx.org, it is a Java program,
so you need to run java too from www.java.com)
https://www.python.org/downloads/windows/ and libraries for opcua, cryptography
using MS-Dos windows C:\Program Files\Python37\Scripts\pip3 install opcua –user
Or (easier to install) Winpython from sourceforge.net/projects/winpyton

And for latter access to the Revolution PLC Pi (RevPI) you can also download
the RevPi control program revpipycontrol_0.7.1.exe (also LGPLv3 open source)
https://revpimodio.org/en/sources/revpipycontrol/

Instead of the IDLE 3 software for Python use, edu environments can also use
the powerful IDE PyCharm EDU from jetbrains.com/pycharm-edu or the community version

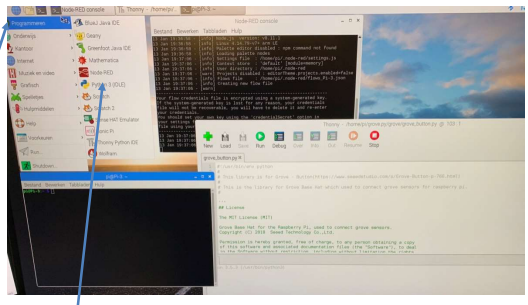
Assignement Intro Pi - Pi login/prompt & windows

(if Pi has a terminal, keyboard and mouse)

Start Pi, get yourself acquainted with Pi & Raspbian and find out it's IP address
login/password: pi/raspberry

$ ip addr ➔ write down your IP number
$ ifconfig

Play around, command as in Unix is
$ ls –als
and start Raspbian windows
$ startx



Via applications menu raspberry icon, programming, Python 3 (IDLE) or Thonny Python
See next slide/page for example.

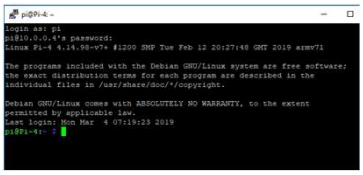
Egbert-jan.sol@tno.nl

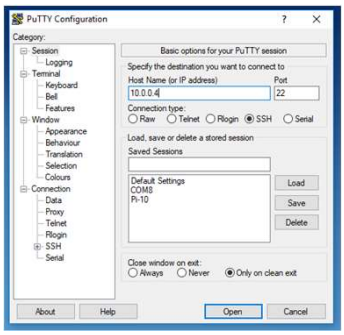
Assignment Intro Pi – needed software for remote login

10.00-10.30 Groupwork 1 - Raspberry Pi intro & remote login (from own notebook)

PuTTY (only for MS-windows), VNC-viewer and Python (all freeware/open source) from

https://www.putty.org





https://www.realvnc.com/download/viewer/ (see two slides furtheron)

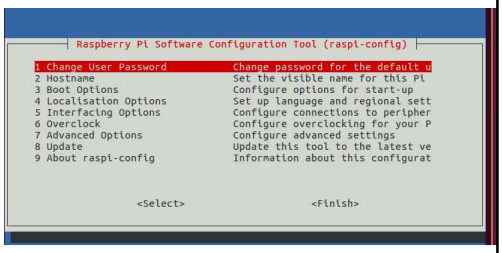
https://www.python.org/downloads/windows/

Instead of the IDLE 3 software for Python use, edu environments can also use
the powerful IDE PyCharm EDU from jetbrains.com/pycharm-edu or the community version

Assignment Intro Pi - remote login (PuTTY command mode)

The access of a Pi from another computer is called headless and can be done either through
a terminal interface as Putty on windows (telnet or SSH) or in a terminal window: ssh on mac
or a windows interface using VNC

Start your notebook (e.g. MS-windows …)
get on the wifi network: smart (password: industry)
using the **IP number of your Pi**
and telnet or ssh to IP nr and login
and experiment with commands as on slide 1-1



Study configuration: $ sudo raspi-config
and e.g. adapt password, activate '3 boot option' from CLI to Desktop
or $ passwd
if you want to change password in terminal/command line mode

Egbert-jan.sol@tno.nl

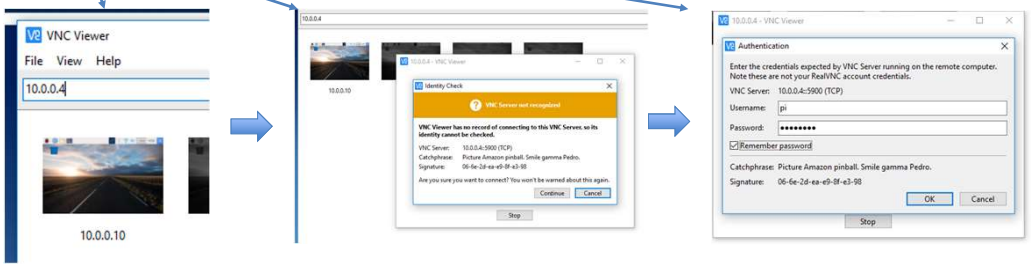
Assignment Intro Pi –VNC (windows mode)

(remote login from own notebook)

RealVNC viewer: (only if Pi has VNC in raspi-config and Pi running in windows mode)

select node (IP nr)

check identity and login, then you get:



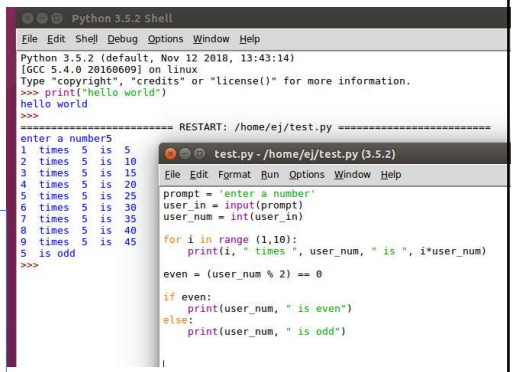
Assignment Intro Pi - programming with Python

in Raspbian windows: programming, Python 3 IDLE

>>> print("Hello world")

Select menu option: file, new, enter text below,

```
prompt = 'Enter a number: '
user_in = input(prompt)
user_num = int(user_in)

for i in range (1,10):
    print(i, " times ", user_num, " is ", i*user_num)

even = (user_num % 2 ) == 0
if even:
    print(user_num, " is even")
else:
    print(user_num, " is odd")
```



and select menu option: run

Egbert-jan.sol@tno.nl

(If you ever have your own Pi – how to install software)

(but for the workshop we did it already)

On your own PC or Mac, download Raspbian from
www.raspberrypi.org/downloads/raspbian/
(takes some time, so have a look at www.raspberrypi.org/help & www.raspberrypi.org/documentation
as well as have a look at https://projects.raspberrypi.org/en/projects and look at e.g. setting up your Raspberry Pi (node-red, …)
and https://learn.adafruit.com/adafruit-raspberry-pi-lesson-1-preparing-and-sd-card-for-your-raspberry-pi)
(if needed unzip the 5GB downloaded file into the *.img file)

Install the downloaded *.img file onto the SD-card using etcher from etcher.io
(but in case you a new, take a look at the raspberrypi.org/help or adafruit lesson to see how etcher works)

Then plug in the SD card in your Pi. Follow the screen instructions and update the software.
After restart, go to preferences and run raspberry pi configuration to activate
system preferences, interfaces (e.g. turn SSH, VNC, I2C and serial on, ..)
(if you are in command line mode, you can use :$ sudo raspi-config and once finished and your want to go to windows, type:$ startx)

For the workshop demo you need the opcua and seeed software (see instructor pages)

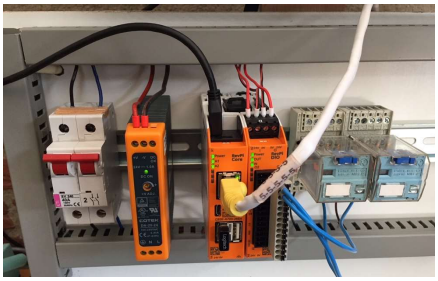
Program

09.30-10.00	Intro with data collection & cyber security on the factory floor and from equipment shop floor example and training course equivalent with Raspberry Pi
10.00-10.30	Assignment 1 – Get remote access to your Pi from own notebook and try Python
10.45-11.30	Data Driven Business trends and key issues (legal, standards, cyber security, ..) - evolution towards open systems (IEC-61131, IETF IP/TCP, Unix/C/Python) - data monitoring & visualization, Digital Twinning, Augmented Reality - from hardwiring (PLC) to visual programming & training of AI/Machine learning - legal issues (of machine/IoT data collection and sharing) - international standards: OPC-UA, Ethernet, TCP/IP, Admin shell
11.30-12.15	Assignment 2 – Collect I/O data from a Pi to your own computer using OPC
13.00-13.45	Cyber security - Explanation of IP/Ethernet networks and how to make them secure
13.45-14.30	Assignment 3 – Collect I/O data from an industrial PLC (RevPi+revpimodio)
15.00-15.30	Data Collection with MQTT
15.30-16.00	Assignment 4 - Secure configuration of for data collecting from Pi and Industrial PLC
16.00-end	You have worked with open source tools to collect data from shop floor & equipment, and understand how to configure and use them in a cyber secure way.

Egbert-jan.sol@tno.nl

Data collection from the factory floor

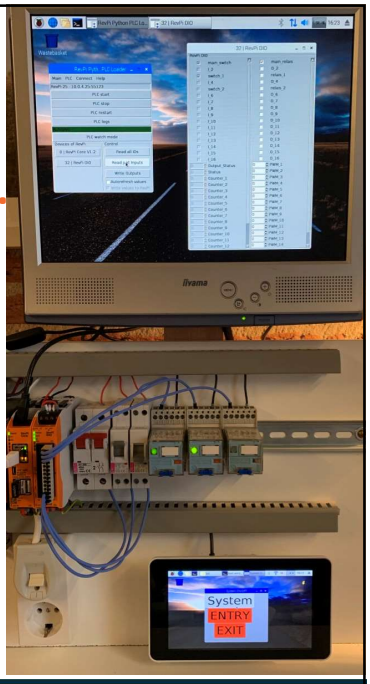
An Ethernet cable plugged into a PLC ……



Data driven

Trends &

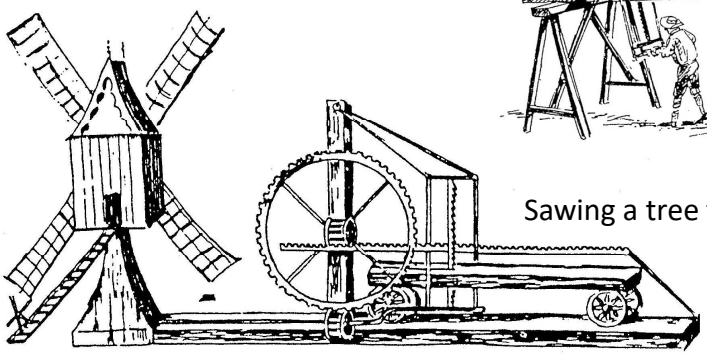
Key issues

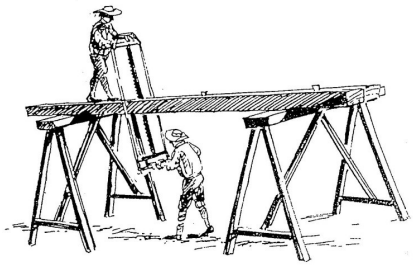


Cornelis Corneliszoon van Uitgeest

Inventor (1593) enabling Holland's Golden Age (1600-1750)

Tekening bij het octrooi voor een door windkracht aangedreven houtzaagmolen dat de Staten van Holland aan Cornelis Corneliszoon van Uitgeest verleende op 15 december 1593



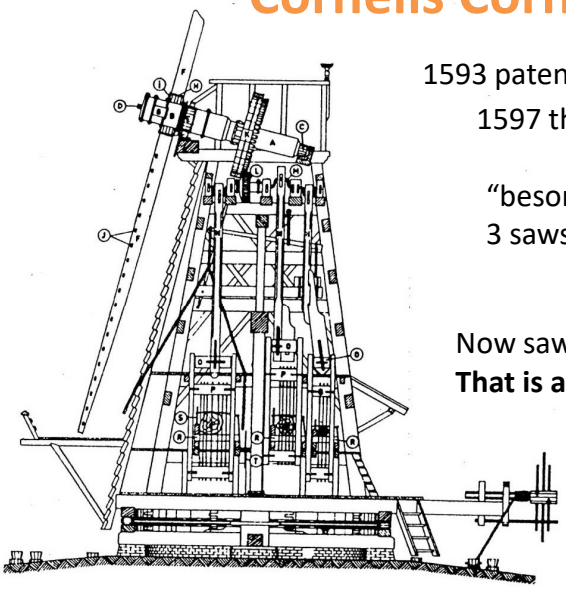


Sawing a tree took 2 men 30 weeks

Pictures from: Cornelis Corneliszoon van Uitgeest, uitvinder aan de basis van de gouden eeuw, Walburg Press

Egbert-jan.sol@tno.nl

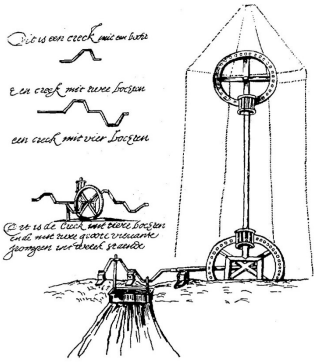
Cornelis Corneliszoon van Uitgeest



1593 patent sawing mill – did not work

1597 the improved crankshaft

"besonder creckwerk"
3 saws at 120°

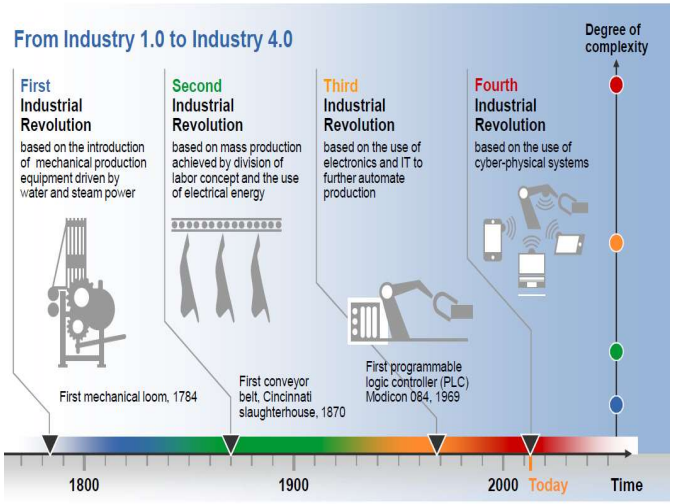


Now sawing a tree took 1 week
That is an improvement of 30 x

By 1670 the Dutch had more then 5000 windmills and world largest fleet

Pictures from: Cornelis Corneliszoon van Uitgeest, uitvinder aan de basis van de gouden eeuw, Walburg Press

Industrial is changing faster



Source: DFKI (2011)

1600 Saw Mill/Sailboot/Wood
180 years, 6 generations

1780 Steam Engine/Steel
110 years, 4 generations

1890 Conveyor belt Mass prod.
70 years, 3 generations

1960 Mainframe, PLC, Robots
40 years, 1 generation

2000 Internet (of Things)
?? 25 years, < 1 generation

2025 Servitization/Sustainability
Agile/Metropolitan Manuf.

Egbert-jan.sol@tno.nl

We can't afford to lose skilled technical people

35 years and above did not got Internet before 1997 at high school when they were 15+

Now we have Internet of Things (IoT) and as a result Smart Industry as we connect everything with everything

5 years from now we will be impacted by Artifical Intelligence, Blockchain with which impacts on business?
And 10 years ahead we can predict that quantum computing will have unknown impact

35 year today implies retirement at 70 year, still 35 working years to go and we can't foresee 10 years.

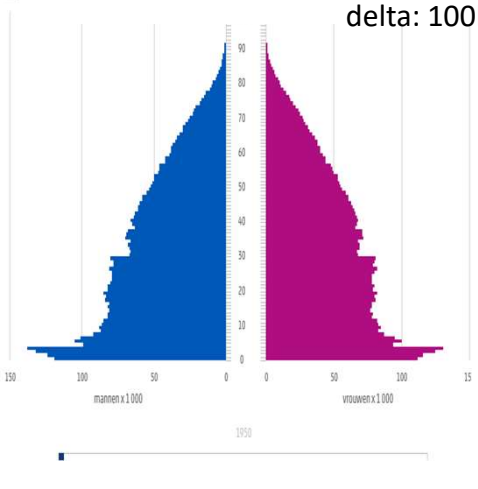
(re-)train every one between 35-60 year to ensure technical people stay on board.

SMART INDUSTRY DUTCH INDUSTRY FIT FOR THE FUTURE

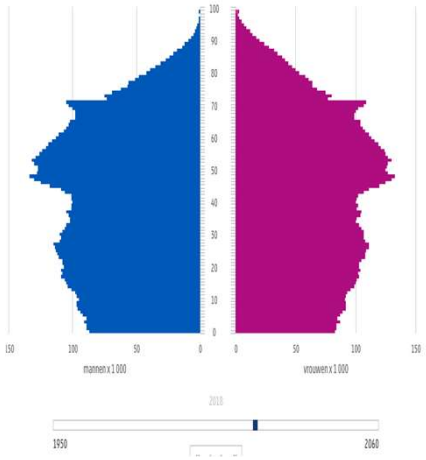
https://www.cbs.nl/nl-nl/visualisaties/bevolkingspiramide

Demographics is changing

NL: 1950 and 10 M inhabitants
2x80k in (20y) and 2x30k out (65 y)
delta: 100k/y



NL: 2018 and 17 M inhabitants
2x100k in and 2x100k out
delta: 0

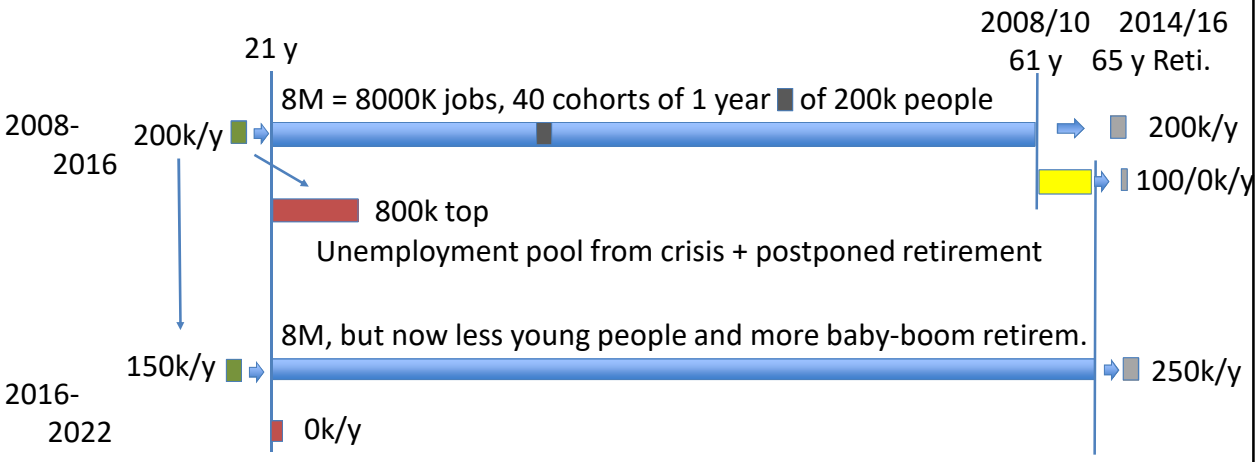


Next 20 years
2x125 k out
2x100 k in
Delta -50k/y
20y x -50k= -1M

SMART INDUSTRY DUTCH INDUSTRY FIT FOR THE FUTURE

Egbert-jan.sol@tno.nl

We face an empty resource pool already today



Economic tension by 2022: 400K unfilled jobs while digitalization accelerates
"You can't afford to loose any 35+ technical schooled employee"

It is about a 200% productivity increase (2015 – 2035 rough NL figures to illustrate)

young+(work+nonwork)+elderly

2015: 16 M = 3 + (8 + 2) + 3, at 8:3 implies 3 working people for 1 retired person
600 B BNP with 8 M = 6 M value creation (contribute to GNP) + 2 (gov/care/edu/def)
600 B by 6 M = **100k/FTE**

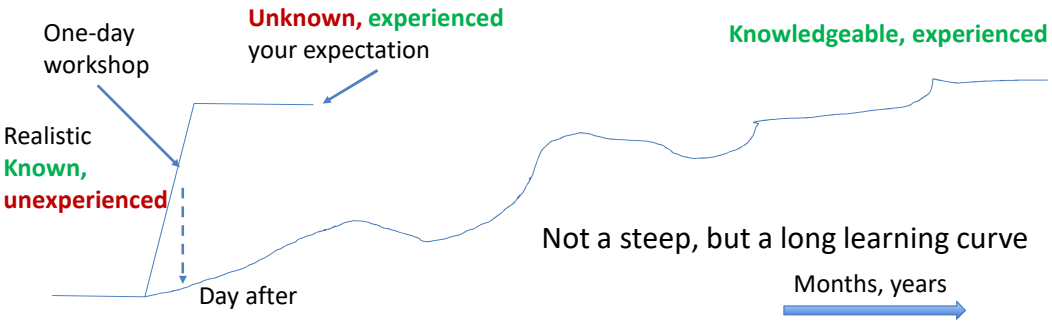
2035: 16 M = 2.5 + (7 + 2) + 4.5 with 6 : 4 , approaching 1 worker for 1 pensionado
50% : 900B BNP = 600 B BNP plus grow 50% in 20 years to cope with 2% inflation
15% : to compenstate less people from 6 M working people in industry/service to 5 M
10-20% 4-4.5 day working and 1-0.5 day life long training
so we need to increase productivity to 180 **k/FTE** for all jobs and even more for industrial jobs.

1 welding team 25+50 years in 2015
in 2035 1 welder at 45 year supervising 2 or 3? robots

Egbert-jan.sol@tno.nl

Lifelong learning for every one

Intermezzo: Monks, Monasteries, and More writing in middle ages



Unknown, unexperienced
Today baby-boom aged PLC programmer using costly, proven, inherent cyber safe Industrial Automation (PLC)

AI with Python data processing

Data visualization with visual prog.

Data collection Standards

Realtime event-Driven control

Cyber secure OS systems

Unix/Python systems

Hardware/Sensor Platform

Who am I

Egbert-Jan Sol (1956)

Ir (Master) in mechanical engineer and PhD on robotics at the TU/e, worked at Hoogovens (now TataSteel), Philips Electronics & Ericsson

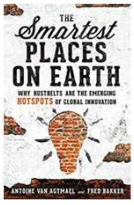
At TNO, the Dutch public RTO (Research & Technology Organisation)
CTO of the TNO Industry board (2003 – today)

At Smart Industry, the Dutch Industrie 4.0 program of the ministry of Economic Affairs, the FME/KMU/NRK (electro/metal/plastic) employers organizations, the CoC and TNO
program director with a focus on the 40 Smart Industry fieldlabs, (2014-today)

At the Radboud University (Nijmegen)
part-time professor (1d/w) on innovation management

Egbert-jan.sol@tno.nl

An open source Smart Industry course created by TNO



Old day: classical knowledge sharing for youngsters in initial education and large company where information/knowledge was sharing & distributed.

Today we need continuous education for all, initial and lifelong, also for those who were not so good at school and only got vocational training with no digital skills and now 35+.

And an economical shift to smaller companies as islands in a **region** where we need to organize **knowledge spillovers** between companies in fieldlabs with digital skills workshop for all.

Regional innovation/knowledge/skill spillover let a region's economic grow. Brainport region 25 y at 4%, rest 2% = 266% vs 166%

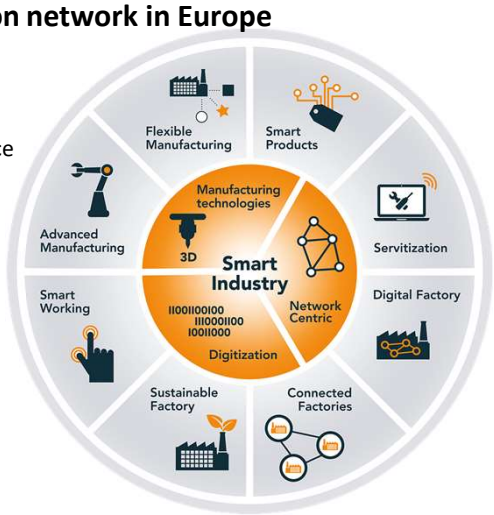
This is an open source workshop where all material is available in source format with one request once you recycled/use it: to refer to the original TNO Smart Industry workshop.

Smart Industry = 2021, ultimate ambitions & next 20 years

By 2021 the Netherlands has developed the best and most flexible digital connected production network in Europe

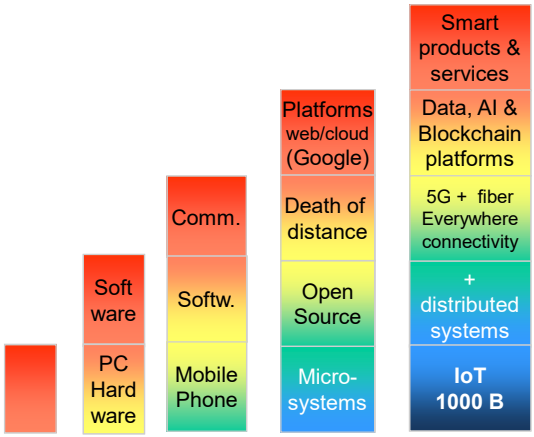
8 transformation with ultimate ambitions

1 Zero defects in production/product:
100% Q-control at each production step
2 Zero-problems at customer site/usage:
100% monitoring of usage of product/service
3 Zero tooling:
3D printing/additive manufacturing
4 Zero delay:
lean manuf, just-in-time, lot size n=1
5 Zero waste
recycling and sustainable energy
6 Zero drop-out
life long learning for every one
7 Zero programming:
2G/3G robots with sensing
8 Zero surprise:
predictive maintenance



Egbert-jan.sol@tno.nl

Smart Industry training challenge: best & most digital connected production netw.



Control – smart: Artif. Intel.

Control – direct

Data visualization & monitoring

Data collection & storage

Sensor data & communication

generic (new) IT knowledge,

programming
(OOP eg. Python
visual (Excel, Node-Red)

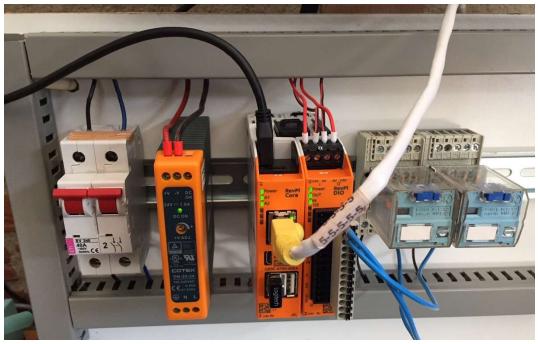
open (datacomm) standards
device-2-device: OPC-UA
factory-2-factory: IDS

3D printers, cobots, RaspberryPi-computers, etc

New knowledge, skills, jobs

Data collection from the factory floor

An Ethernet cable plugged into a PLC ……



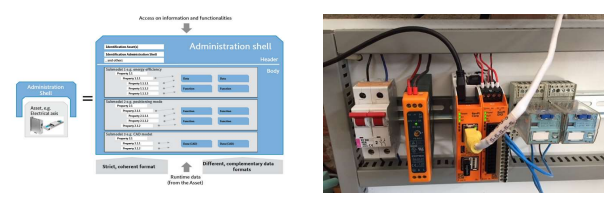
Egbert-jan.sol@tno.nl

… towards the office net, clouds, …
and facing challengence as standards, cyber security, legal ..

Data usage & **App layer**

Data share & **Store layer**

Sensor/IoT **Collect layer**



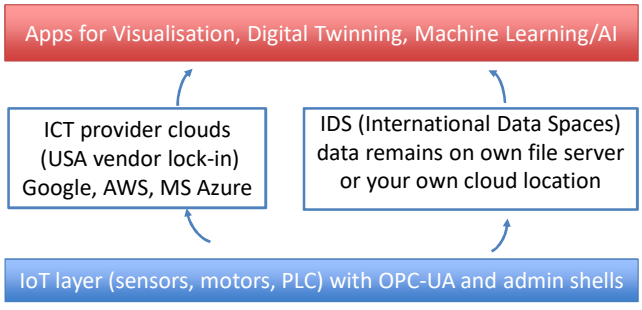
Industrial Data

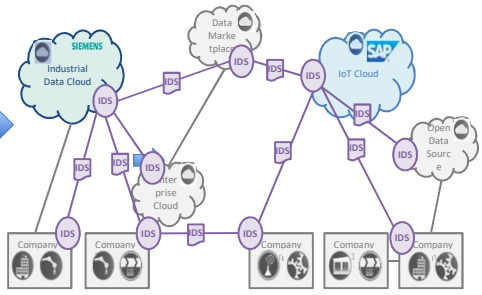
Layers:

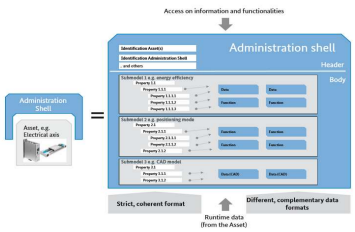
App

Store

Collect







IDS International Data Spaces

(was Industrial Data Space)

European approach where you remain owner of your own data (data sovereignty) and make it available for others under your conditions

Egbert-jan.sol@tno.nl

Data in business & industry

Type of Data in industry:
Company data (operational, div.)
Customer and persoon data (NAW)
Order & Logistic data
Payment and billing data
Contract Data
Product Data
Production process Data

- Data Use
  - Less costs
    - Intern mgt
      - Automation
      - Optimizat.
    - Lower risks
      - Risk access.
      - Incid. mgt
  - More return
    - New busin.
      - Improve
      - New servic.
    - Marketing
      - Promotion
      - Relations
  - Societal aspects

AI/ Machine Learning
Data visualisation
Traceability
Product/ service monitoring

Data in business & industry

- Challenges of Data Use
  - Operational
    - Access & availability
    - Standards
    - Sovereignty
    - Cyber Security
  - Expertise
    - Tools
    - Knowledge
  - Financial
  - Societal aspects
    - Opportunity awareness by people
    - Trust
    - Legal Aspects

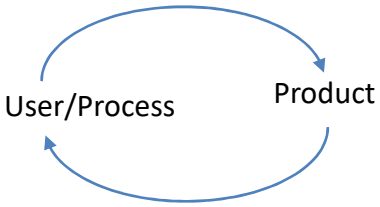
This workshop

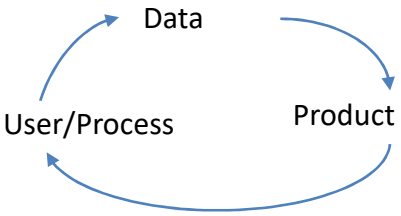
Egbert-jan.sol@tno.nl

Why is data today so important for product innovation & service/process improvement

Yesterday (although many still today)

You watch/interview a few users on how they use your product
or you sample some quality data on your manufacturing process

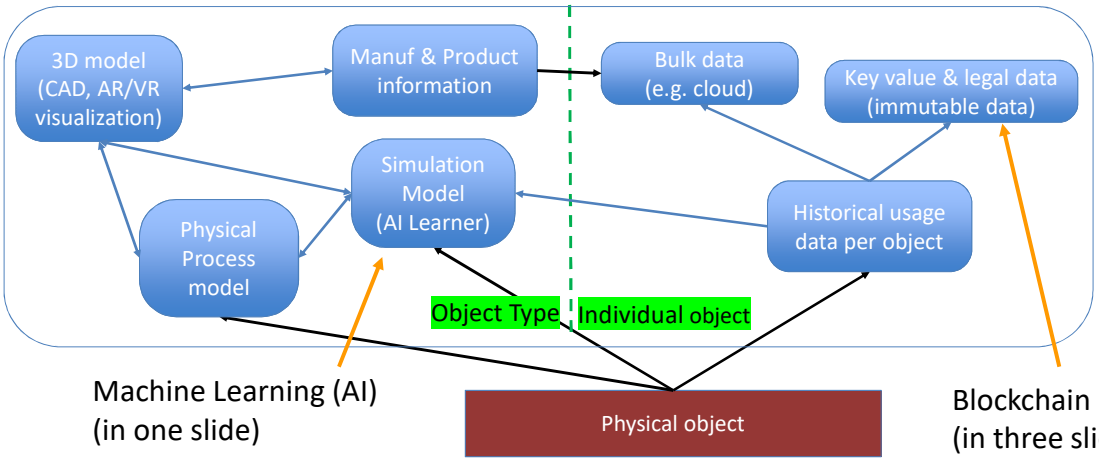




Way of working of advanced companies collecting usage data of all users of their smart products or do 100% Q-control on each production step
The more data, the larger the competitive advantages

Digital Twinning in design & use phase + 2 digital technologies

Digital Twin is a "living" digital representation of the physical object
DT (Digital Twin– design of the object) and DTI (Instance – individual object)



Machine Learning (AI)
(in one slide)

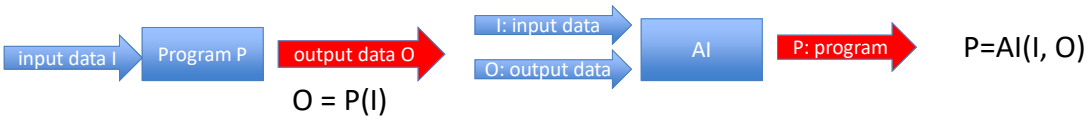
Blockchain (DLT)
(in three slides)

Egbert-jan.sol@tno.nl

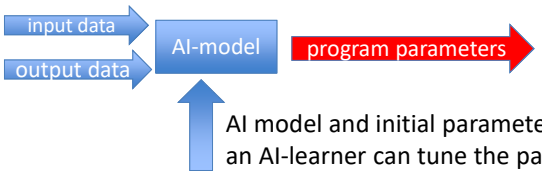
Artificial Intelligence or better Machine Learning

AI-hypes go up and down (already two or more AI winters since 1960)

The AI-holy grail & the misperception – input + output => program : no more programming



Now comes the small letters: In real-life there is no AI master algorithm, just as with "Data" you won't get your Product

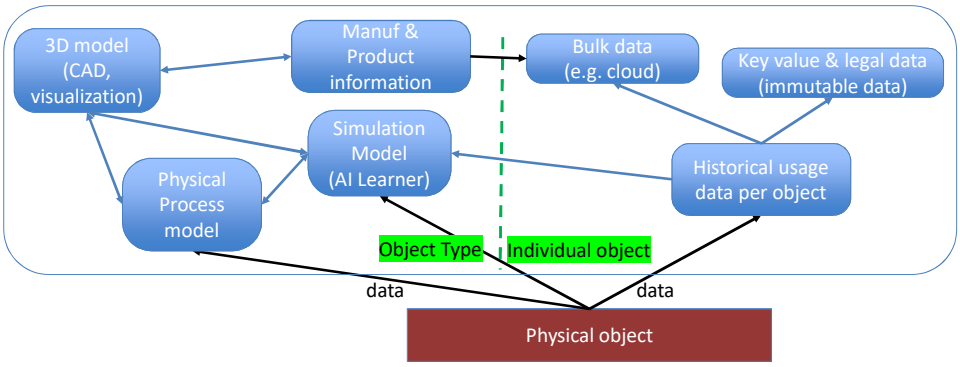


AI-models: neural networks,
evolving programs with selection,
physical process models, Bayes statistics, ..

AI model and initial parameters and with machine learning
an AI-learner can tune the parameters such that with new input produces new output

Digital Twinning in design & use phase – other technologies

Next to techn. as
- Cloud storage/IDS
- AI/Machine Learn.
- Blockchain with Digital Identifiers



There is more in DT:

- Augmented (& Virtual) reality – now easy possible by e.g. ARKit as in the iPhone (see Ikea app) and to be used in e.g. maintenance of equipment (online manuals, instructions, etc)
- Standards, not on interface protocols, but also on the meaning of data (semantics)
- Legal aspects as privacy (GDPR), but lacking copyrights on sensor data, databank laws, etc)

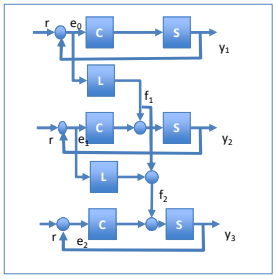
Egbert-jan.sol@tno.nl

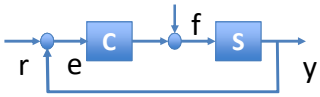
Data usage at different levels

Level	Description	at **home**	Industrial OT	I40/Smart Industry
AI/ML/smart	Adaptive system.	Google Assistent Alexa, Siri	Google Cloud AWS, Azure	IDS
Application layer	*WAN/worldwide*			
Monitoring & Control	Screens AR/VR	Mobile apps Hue, Home	SCADA	AR/VR, Node-red
Interface	*Fiber/mobile*	*HTTP/GPRS*		*OPC-UA*
Data Store layer	USB stick disk, cloud	Synology Office365 iCloud	Propri. PLC	Open PLC
Interface	*Wired/wireless*	*Wifi/bluetooth*	*Profibus, etc*	*Ethernet*
Data collect, IoT, Physical layer	cheap sensors	Philips Hue Ikea Tradfre Netatmo, Nest	24 VDC	24 VDC

Data usage at different levels

Level	Description
Artificial Intell. /ML/smart control	Adaptive system: Smart control
Application layer	*Dataprocessing/data cleaning/Artificial Intelligent/ machine learning/advanced control engineering*
Monitoring & Control	Control: manual with visualization simple automatic control
Interface	*Python, visual programming, etc*
Data layer	Realtime data or Database storage
Interface	*Ethernet / IP / OPC-UA*
Data collect, Physical layer	10-100:1 I/O (e.g. 24Volt DC)





System with feedback (e)/ feedforward (f) Controller

System with Inputs and Outputs

Egbert-jan.sol@tno.nl

Legal issues - Licences

Open systems

you can use it freely, but improvements must be made public (e.g. github, own web)

Unix OS environments: often LGPL

The **GNU Lesser General Public License** (**LGPL**) is a free-software license published by the Free Software Foundation (FSF). The license allows developers and companies to use and integrate software released under the LGPL into their own (even proprietary) software without being required by the terms of a strong copyleft license to release the source code of their own components. For proprietary software, code under the LGPL is usually used in the form of a shared library, so that there is a clear separation between the proprietary and LGPL components. The LGPL is primarily used for software libraries, although it is also used by some stand-alone applications.

Be carefull

hardware (equipment) is sometime sold, but with a licence for the software

once vendor goes broke, can you still use software?

read/watch your contract on all equiment, etc.

open source can still be used, but changes continously …

Legal issues - Sensor Data, Copyright, Databanken wet

Copyright is goed bekend, maar is alleen van toepassing op creative/intellectuele arbeid

Sensor data valt niet onder copyright wetgeving.

Data delen vereist dan ook apart contract met afspraken over toegang, opslag, beheer, etc.

Vanuit Smart Industry Dare-2-Share voorbeeld openbaar beschikbaar gemaakt

Databanken wet (1999)

Het **databankenrecht** is de tak van het recht die de intellectuele eigendom van databanken regelt. Het recht geeft een beperkte bescherming aan de maker van generieke databanken waar die geen beroep op het auteursrecht kan doen.

Is een lastiger onderwerp: kleine letters zoals

Artikel 1 lid 1 sub a Databankenwet:

"databank: een verzameling van werken, gegevens of andere zelfstandige elementen die systematisch of methodisch geordend en afzonderlijk met elektronische middelen of anderszins toegankelijk zijn en waarvan de verkrijging, de controle of de presentatie van de inhoud in kwalitatief of kwantitatief opzicht getuigt van een substantiële investering;

Egbert-jan.sol@tno.nl

Legal issues - Dare-2-Share from SI website

De Dare-2-Share samenwerkingsovereenkomst behartigt de belangen van de diverse partijen op een evenwichtige wijze.
Overigens neemt dit niet weg dat bedrijven en organisaties een eigen verantwoordelijkheid hebben zich goed juridisch te laten voorlichten over hun positie in het kader van een samenwerking en het delen van intellectueel eigendom c.q. data.

Stappenplan Dare-2-Share overeenkomst https://www.smartindustry.nl/wp-content/uploads/2018/08/dare-2-share_agreement.docx
1.Juridische randvoorwaarden
2.Vertrouwde Informatiebeheerder of broker
3.Uitleg verschillende componenten Dare-2-Share
De Dare-2-Share overeenkomst is opgemaakt uit verschillende componenten.
Deze componenten hangen af van de vorm van samenwerking die wordt aangegaan met de verschillende partijen.
Waar moeten partijen aan denken? Wat spreek je zoal af?
Deze overeenkomst dient als praatplaat en kan dus niet zonder meer worden gekopieerd voor de eigen situatie.
Er is gekozen voor een platformconstructie met een vertrouwde informatiebeheerder of broker (zie bovenstaande uitleg bij stap 2).

> 1. JURIDISCHE RANDVOORWAARDEN

> 2. VERTROUWDE INFORMATIEBEHEERDER OF BROKER

> 3. UITLEG VERSCHILLENDE COMPONENTEN SAMENWERKINGOVEREENKOMST

Meer weten?
Kijk op www.smartindustry.nl/data-delen of neem contact op met het programmabureau Smart Industry via info@smartindustry.nl.

Legal issues - Juridische Randvoorwaarden

> 1. JURIDISCHE RANDVOORWAARDEN

Samenwerken is de essentie van Smart Industry. Voordat het samenwerken wordt gestart, moeten afspraken zijn vastgelegd voor het geval een van de partners nieuwe algoritmen ontwikkelt met de gemeenschappelijke data. Het ligt voor de hand dat die partner in principe rechthebbende is of wordt ten aanzien van het algoritme zelf (maar niet per definitie van de data). Als er geen afspraken zijn gemaakt kan iedere partner met toegang tot de data dit doen en is hij vrij in het gebruik van het algoritme. Een simpele afspraak kan zijn dat de andere partners ook over het gebruik van het algoritme mogen beschikken.

Een afspraak kan bijvoorbeeld zijn dat partners (de feitelijke bezitters van de data) naar rato van hun bijdrage in de omvang van de dataverzameling voor gezamenlijke rekening een partij (bijv. een van de partners, een externe partij of een gemeenschappelijke nieuw op te richten entiteit, bijv. een stichting of BV) een algoritme laten maken die daarmee waarde creëert die net als een licentiecontract (gebruiksrecht) regelmatig een gebruikersafdracht naar de bijdragende partijen doet. Het ontwikkelen van het algoritme is creatieve arbeid waarbij meer kennis komt kijken dan alleen de meetdata verzamelen. Een dergelijke partij kan overigens meerdere algoritmen ontwikkelen. Middels deze constructie is het de bedoeling dat de oorspronkelijk eigenaar van de meetdata betaald kan worden als de data (op termijn) waarde oplevert.

Egbert-jan.sol@tno.nl

Legal issues - Vertrouwde Informatiebeheerder

> 2. VERTROUWDE INFORMATIEBEHEERDER OF BROKER

(Juridische) afspraken bieden niet altijd uitkomst om uitdagingen in de innovatiefase op te lossen. Om dit (eenvoudiger) mogelijk te maken kunnen partijen in hun samenwerkingscontract de oprichting van een Dare-2-Share juridische entiteit (eenheid) afspreken die de betreffende (meet)data van de deelnemers beheert en bijvoorbeeld een mechanisme voor lokale of centrale opslag als informatie broker (onafhankelijke tussenpersoon) en/of trusted third party (vertrouwde derde partij ook wel vertrouwde tussenpersoon) organiseert. Hierbij maken we gebruik van het principe dat intellectueel eigendom c.q. (meet)data geen aanwijsbare eigenaar heeft.

In de voorwaarden van deze juridische entiteit wordt ook vastgelegd hoe over verdere condities voor openstelling en informatiebeveiliging wordt besloten en over afspraken over betrouwbaarheid, wijze van aanleveren en kwaliteit van de data, standaarden e.d. Nb Er zal voor gewaakt moeten worden dat zich geen machtsblokken vormen die zouden kunnen leiden tot uitsluiting van anderen en strijdig zijn met het mededingingsrecht (het recht met betrekking tot concurrentie).

Legal issues - Samenwerkingsovereenkomst

Download Samenwerkingsovereenkomst

https://www.smartindustry.nl/wp-content/uploads/2018/08/dare-2-share_agreement.docx
(er is ook een vertaalde engelse versie beschikbaar)

> 3. UITLEG VERSCHILLENDE COMPONENTEN SAMENWERKINGOVEREENKOMST

Zie hieronder de uitleg per onderdeel van de samenwerkingsbijeenkomst:

Partijen: Allereerst dienen de betreffende samenwerkende 'partijen' in het contract opgenomen te worden.

Overwegende dat: Daarna wordt onder 'Overwegende dat' de intenties van de partijen weergegeven.

Hoofdstuk 1 definities: Hierin staan de veel voorkomende begrippen die in de samenwerkingsovereenkomst staan, zodat er achteraf bijvoorbeeld geen onenigheid kan ontstaan over de uitleg van 'data' of een 'gebruiker'.
……
…….
Hoofdstuk 15 Overige bepalingen: …

Egbert-jan.sol@tno.nl

Summary message

Fourth Industrial Revolution - acceleration of digitalisation of industry

From the costly, proprietary systems to today's IoT connecting everything with everything

Smart products/equipment/manufacturing processes will provide large amount of data
which we can process to lower costs
and improve performance/returns,
where still a lot can and need to be done, technically and in skills training
as hardware is cheap, open source software is very powerful, but
where skills and availability of capable people is the limiting factor

Increase the digital skills of every one: it's not enough to leave it to ICT people only

Like the monks in the middle ages who wanted to do more writing and therefore needed more monasteries, but society decided it needed to do it themselves

Program

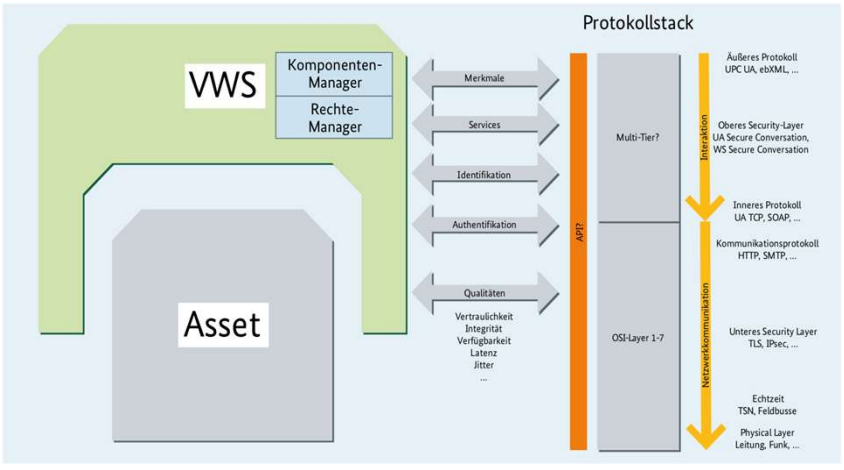
13.00-14.30	Introduction industrial revolutions, productivity, people scarcity & lifelong learning challenge data use + demo warehouse control hooking up sensors/equipment/PLC to the Internet …. Bang.
14.30-15.15	Data on the Factory Floor from classical PLC with 1/1 IO and cycle loop to 10-100/1 I/O and event program. from very technical to legal & business issues
15.15-15.30	Break
15.30-16.00	OPC standard, other standards & cyber security
16.00-16.30	Demonstration using open source PLC, software, etc.
16.30-end	Conclusion & Closure

Egbert-jan.sol@tno.nl

Program

09.30-10.00	Intro with data collection & cyber security on the factory floor and from equipment shop floor example and training course equivalent with Raspberry Pi
10.00-10.30	Assignment 1 – Get remote access to your Pi from own notebook and try Python
10.45-11.30	Data Driven Business trends and key issues (legal, standards, cyber security, ..) - evolution towards open systems (IEC-61131, IETF IP/TCP, Unix/C/Python) - data monitoring & visualization, Digital Twinning, Augmented Reality - from hardwiring (PLC) to visual programming & training of AI/Machine learning - legal issues (of machine/IoT data collection and sharing) - international standards: OPC-UA, Ethernet, TCP/IP, Admin shell
11.30-12.15	Assignment 2 – Collect I/O data from a Pi to your own computer using OPC
13.00-13.45	Cyber security - Explanation of IP/Ethernet networks and how to make them secure
13.45-14.30	Assignment 3 – Collect I/O data from an industrial PLC (RevPi+revpimodio)
15.00-15.30	Data Collection with MQTT
15.30-16.00	Assignment 4 - Secure configuration of for data collecting from Pi and Industrial PLC
16.00-end	You have worked with open source tools to collect data from shop floor & equipment, and understand how to configure and use them in a cyber secure way.

Administrative shell for factory equipments, ... assets



Sichere Implementierung von OPC UA für Betreiber, Integratoren und Hersteller, April 2018, BMWi,

Egbert-jan.sol@tno.nl

It is a long way from *Incompatible* to *Interoperable* and beyond

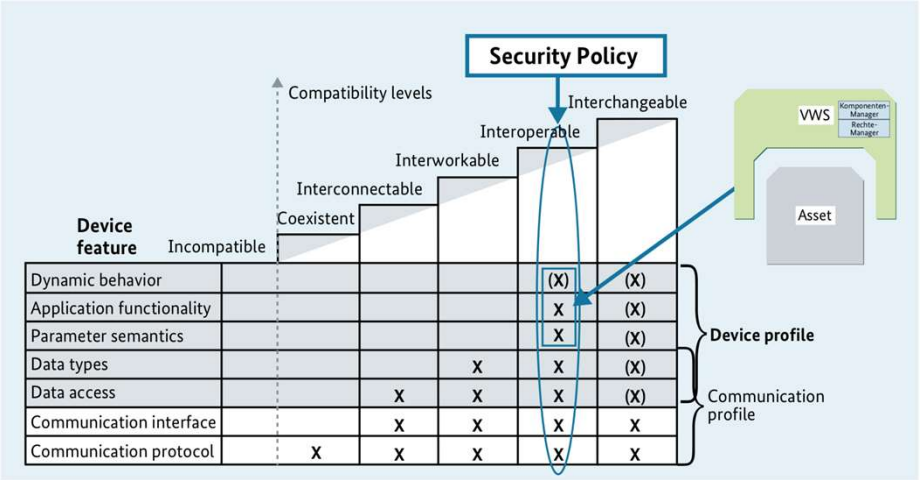
from: Sichere Implementierung von OPC UA für Betreiber, Integratoren und Hersteller

XML is beyond HTML
(Hyper Text Markup Language)

```
<!DOCTYPE html>
<html>
  <head>
    <title>This is a title</title>
  </head>
  <body>
    <p>Hello world!</p>
  </body>
</html>
```

XML (Extensible Markup Language)

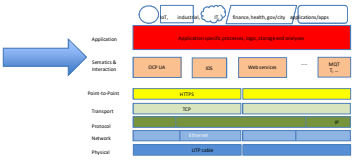
TCP/IP & Ethernet



Sichere Implementierung von OPC UA für Betreiber, Integratoren und Hersteller, April 2018, BMWi,

Communication Layer Architecture

(transmission layers 1-4 (point-to-point transport part)

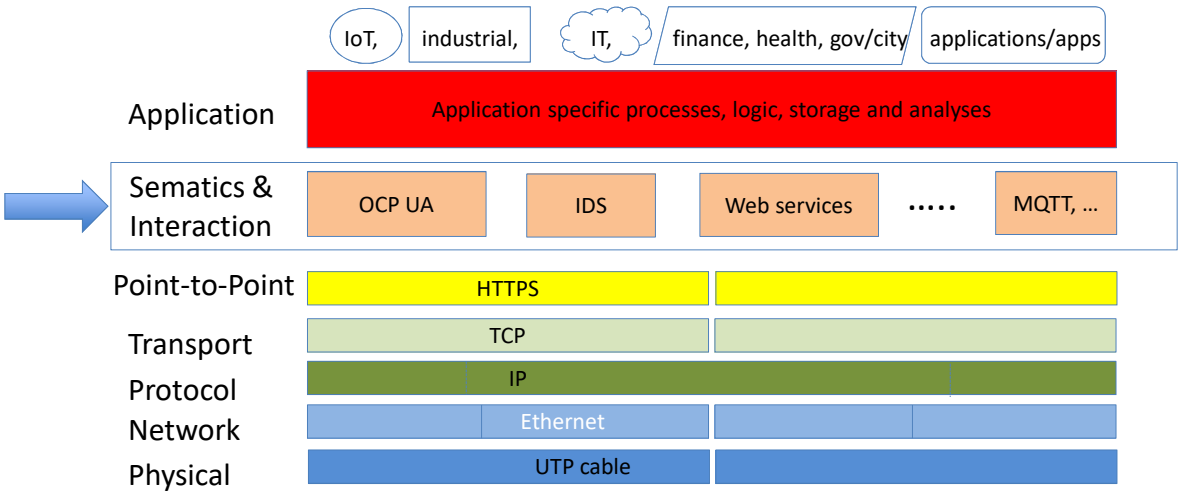


L5-7:
Applications/Apps (e.g. web based): IoT | industrial | IT | finance, health, gov/city | consumer

Point-to-Point	TLS/HTTPS	DTLS (S=security)
L4 Transport e.g. TCP	TCP	UDP
L3 Protocol e.g. IP	IETF DetNet	IPv4/IPv6 / 6LoWPAN
L2 Network e.g. Wifi	Time critical / IEEE 802.3 Ethernet	IEEE 802.11 WLAN / IEEE 802.15.4
L1 Physical Layer (Lx = ISO layer x)	Wired (e.g. UTP cable)	Radio

Egbert-jan.sol@tno.nl

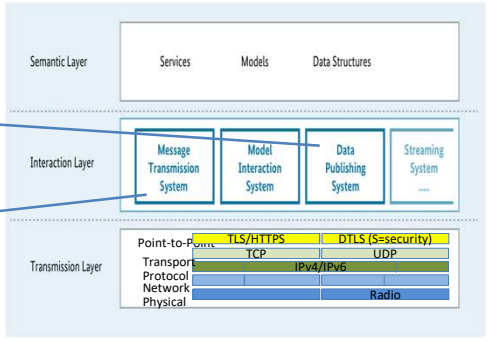
Layered Architectures



Layered Architectures – Interaction layer

MQTT: Messages Queueing Telemetry Transport
simple IoT protocol
open source: Mosquitto (python), MQTT.fx (java)
1:n (1) publisher/(n) subscriber interaction model

OPC-UA (Open Platform Comm. – Unif. Architecture)
machine to machine communication
client/server interaction model
open source: FreeOPCAU (python)+cryptography
used in Industrie 4.0 equipment to equip/gateway

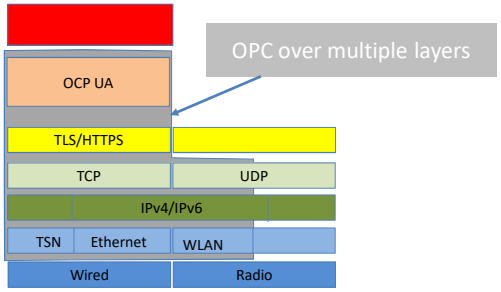


Sichere Implementierung von OPC UA für Betreiber, Integratoren und Hersteller, April 2018, BMWi,

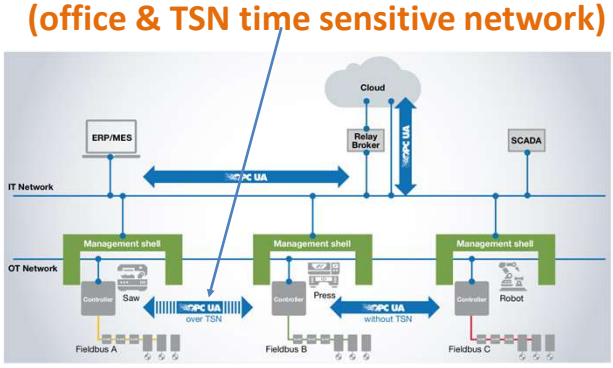
IDS (International Data Space)
connector model (client/server, pub/sub, future blockchain - preconfigured and arranged
used between companies/factories/different entities

Egbert-jan.sol@tno.nl

OCP UA: the coming I40 standard for indus. equip.



(office & TSN time sensitive network)



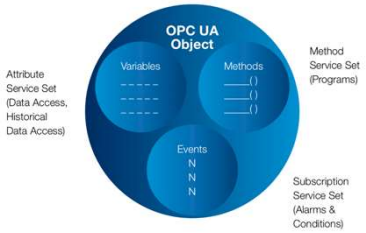
Evolved from a Windows protocol
(Ole for Process Control/DCOM)
Now IEC62541 standard and many implementations

https://opcfoundation.org/

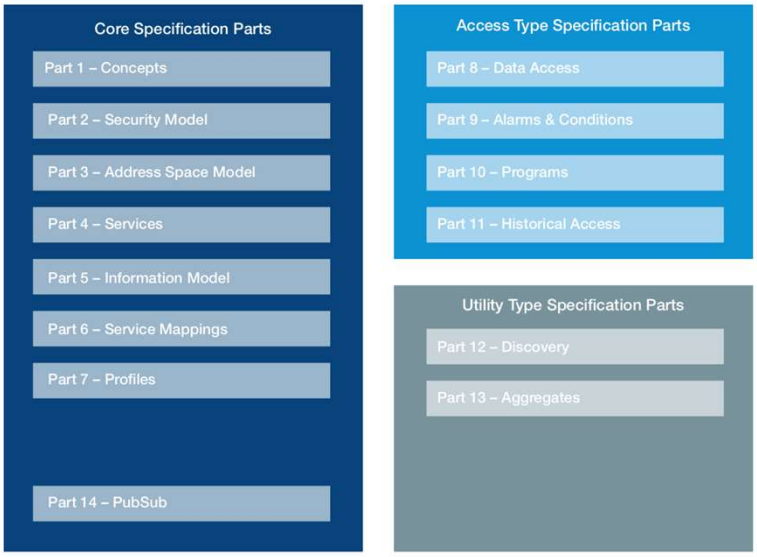
OPC-UA (Open Platform Communication – Unified Architecture) is more complex then MQTT:
over more layers, more extensions as over time sensitive and office
available in Pi's, PC's and PLC's (with 24VDC Digital and Analoge sensor/actuators)

OPC UA standard

2006 -> 2018
14 doc's, 1250 pages



https://opcfoundation.org/

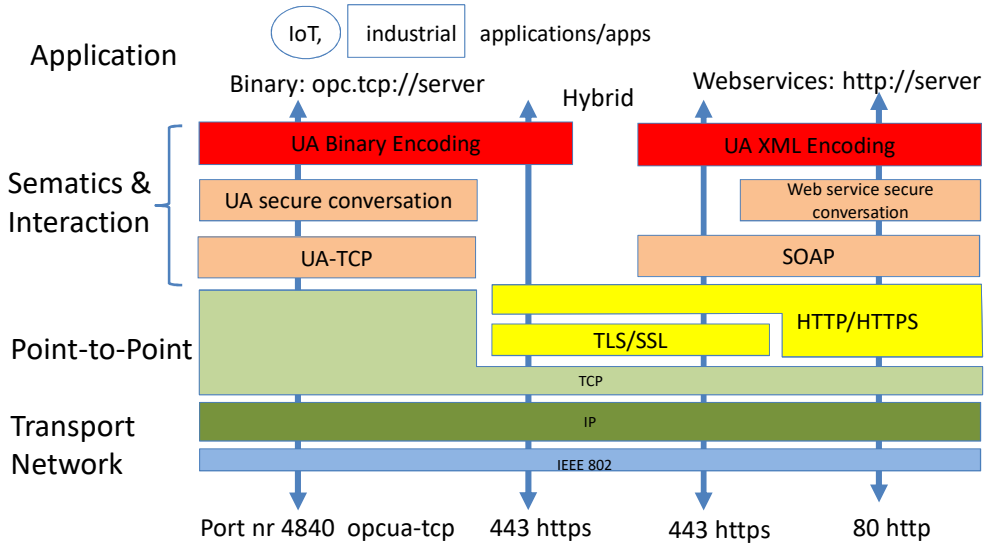


IEC62541: OPC UA specifications

Egbert-jan.sol@tno.nl

OPC UA binary vs XML Services

Binary protocol:
No XML parser,
No SOAP, etc
For embedded devices
Read access
Event triggers
Heartbeats
Redundancy
Buffering



Sichere Implementierung von OPC UA für Betreiber, Integratoren und Hersteller, April 2018, BMWi,

HTML, XML, OPC UA namespaces

Hyper Text Markup Language e.g.:

```
<!DOCTYPE html>
 <html>
    <head>
       <title>
          This is a title
       </title>
    </head>
    <body>
       <p>Hello world!</p>
    </body>
</html>
```

HTML is used in HTTP (Hypertext Transfer Protocol) to transmit webpages with text and today images, etc.

XML is used to represent data structures in both human and machine readable form. It contains datatypes, namespaces, etc.

from Wikipedia

eXtensible Markup Language e.g.:

```
<?xml version="1.0"?>
<quiz>
 <qanda seq="1">
  <question>
   Who was the forty-second
   president of the U.S.A.?
  </question>
  <answer>
   William Jefferson Clinton
  </answer>
 </qanda>
 <!-- Note: We need to add
  more questions later.-->
</quiz>
```

XML

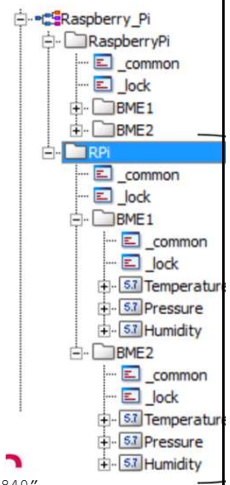
```
Python opcua clientserver example:

from opcua import Client

url = "opc.tcp://10.0.4.42:4840"
client = Client(url)
client.connect()
p_bme1 = client.get_node("ns-2:i=2")
pressure_BME1 = p_bme1.get_value()
…
```

OPC UA

Binary TCP version from sensor/machine communication (ocp.tcp://10.0.4.2 vs https://xx)

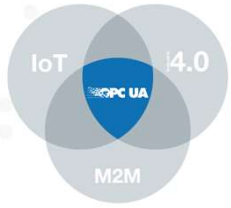
OOP (object oriented program.)
Nodes
with their attributes, methods and trigger events
Clients ask for server profile

```
Python opcua server example:

from opcua import Server
server = Server()

url = "opc.tcp://10.0.4.42:4840"
server.set_endpoint(url)

name = "RPi"
addspace = server.register_namespace(name)
node = server.get_objecs_node()
bme1 = node.add_object(addspace, "BME1")
press = sensors.add_variable(addspace,"pressure",0)
….
```



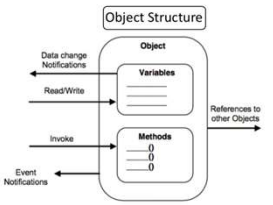
Egbert-jan.sol@tno.nl

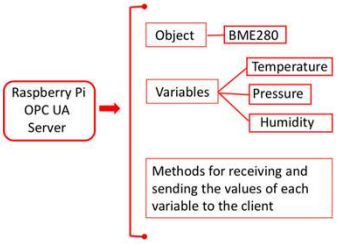
OPC UA implementation from Siemens down to open Raspberry Pi's

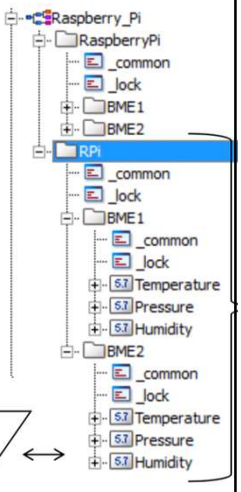


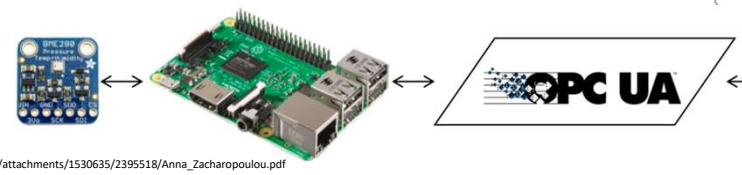
OPC UA Raspberry Pi Server

- The structure of OPC UA Server is based on **AddressSpace Model** which represents all the **Objects** that the Server sends to Clients.
- Every Object consists of **Variables** and **Methods**.
- Packages: '**FreeOPCUA**' (entirely in Python), **cryptography** (security reasons)









2017 https://indico.cern.ch/event/667256/contributions/2732843/attachments/1530635/2395518/Anna_Zacharopoulou.pdf

SMART INDUSTRY DUTCH INDUSTRY FIT FOR THE FUTURE

OPC-UA open platform communication – united architecture

OPC UA

USA: industrial internet CONSORTIUM

Japan: IVI Industrial Value Chain Initiative

China: Made 2025 opc-au ch 1-12 made Chinese national standard

Korea: Manufacturing Industry Innovation MII3.0

Germany: PLATTFORM INDUSTRIE 4.0

Netherlands: smart industry

But be warned, it's not an easy protocol due to all its flexibility

SMART INDUSTRY DUTCH INDUSTRY FIT FOR THE FUTURE

Assignment IoT I/O on a Pi & OPC-AU example

11.30-12.15 Groupwork 1 – Collection I/O data from a Pi to your own computer using Python

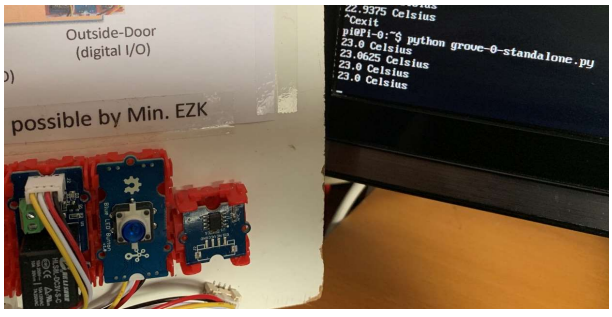
For 2) OPC: You need to install C:\Program Files\Python37\Scripts\pip3 install opcua -user
and for monitoring from same or other PC you might use a OPC-viewer as UaExpert
from https://www.unified-automation.com/products/development-tools/uaexpert.html

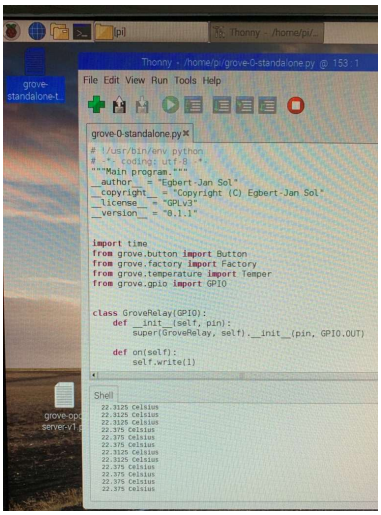
Example:
0) grove-0-standalone.py (only I/O control, no user interface)
1) grove-1-standalone-tkinter.py
(I/O control + data monitoring + user interface in Python tkinter)
(program with control en UI gets long and less well maintainable due to complexity)
2) grove-2-opc-server on Pi with I/O and
grove-2-opc-client on Pi or PC with monitoring & user interface
(modular software, I/O control & OPC on Pi,
user interface and data visualization at 2nd Pi or other computer (notebook)

Assignment IoT I/O on a Pi & OPC-AU example

Example:
0) grove-0-standalone.py (only I/O control, no user interface)
in windows mode, click on icon

or in command line: …$python3 grove-0-standalone.py

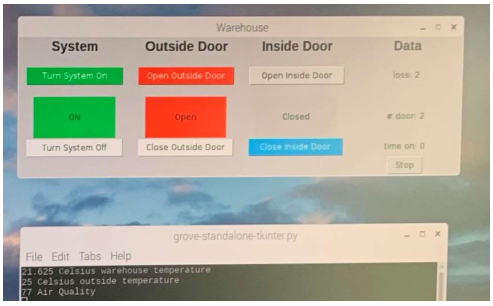


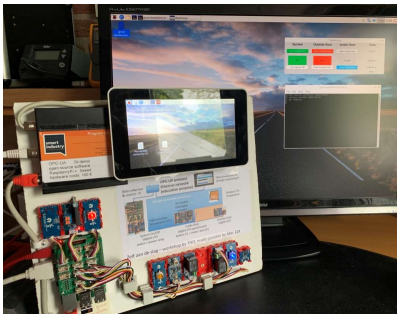


Egbert-jan.sol@tno.nl

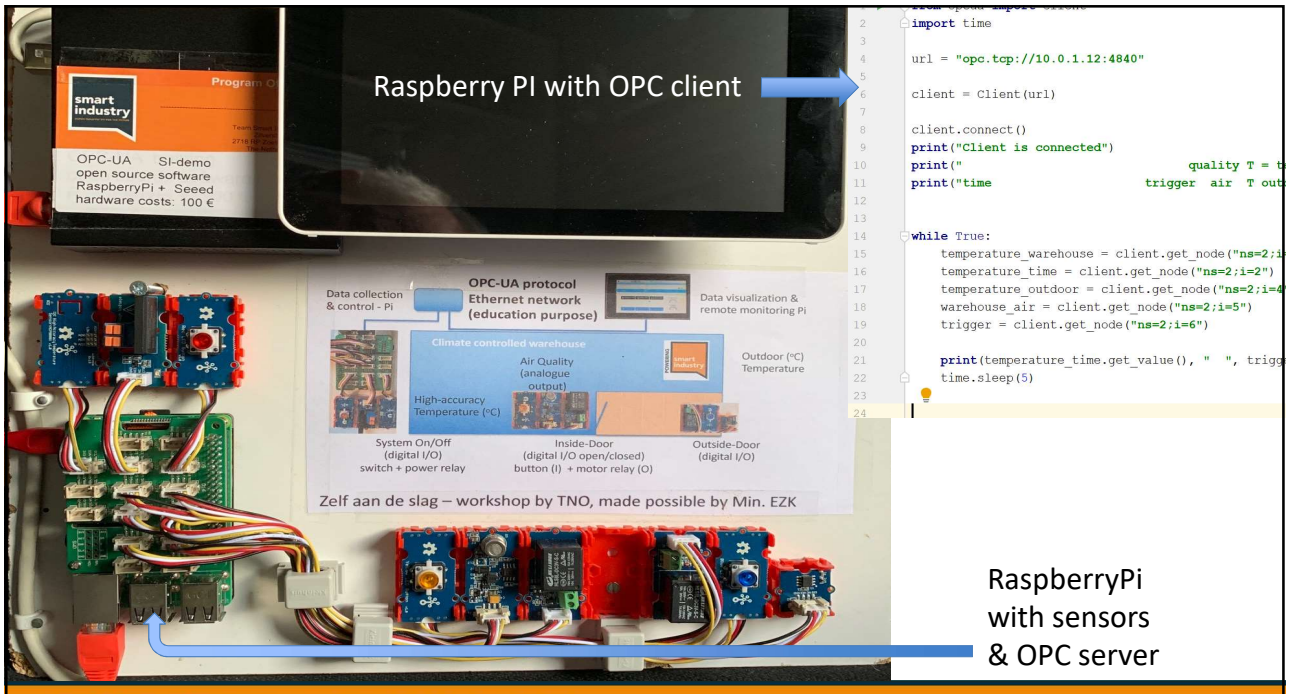
Assignment IoT I/O on a Pi & OPC-AU example

Example:
0) grove-0-standalone.py (only I/O control, no user interface)
1) grove-1-standalone-tkinter.py (I/O control + data monitoring with user interface in Python tkinter)
(program with control en UI gets long and less well maintainable due to complexity *))

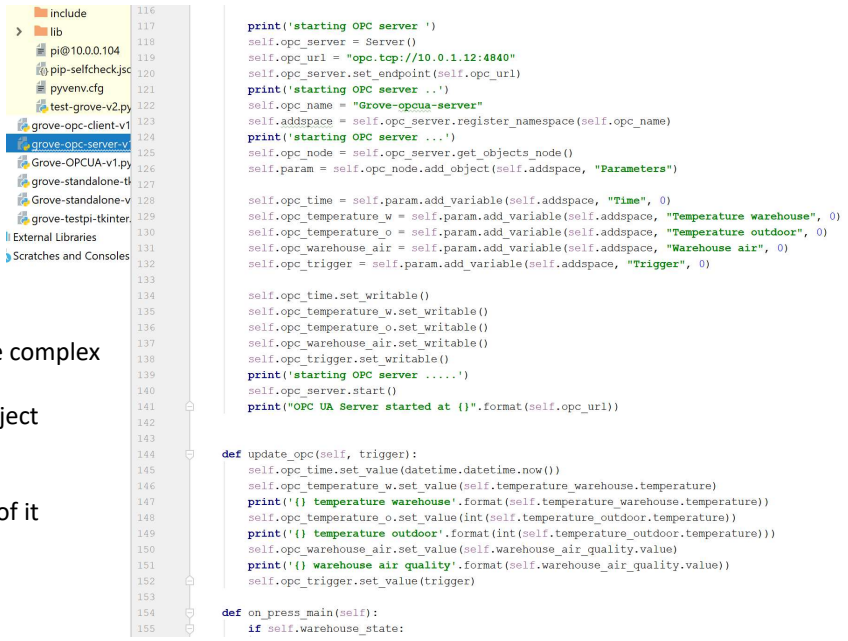




*) note on software maintenance: for user interface on Pi, you must run it in Raspbian windows mode (which starts a lot of other tasks) mixed with I/O control, in case only I/O control and OPC software on Pi software remains clearer.



Egbert-jan.sol@tno.nl



Coding for an OPC Server is more complex

Addspace, Namespace, node, object

And then comes security on top of it

… (SI workshop afternoon)

Program

13.00-14.30	Introduction industrial revolutions, productivity, people scarcity & lifelong learning challenge data use + demo warehouse control hooking up sensors/equipment/PLC to the Internet …. Bang.
14.30-15.15	Data on the Factory Floor from classical PLC with 1/1 IO and cycle loop to 10-100/1 I/O and event program. from very technical to legal & business issues
15.15-15.30	Break
15.30-16.00	OPC standard, other standards & cyber security
16.00-16.30	Demonstration using open source PLC, software, etc.
16.30-end	Conclusion & Closure

Egbert-jan.sol@tno.nl

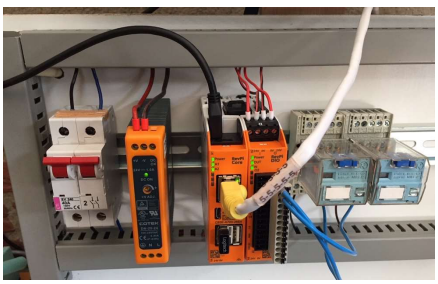
Program

09.30-10.00	Intro with data collection & cyber security on the factory floor and from equipment shop floor example and training course equivalent with Raspberry Pi
10.00-10.30	Assignment 1 – Get remote access to your Pi from own notebook and try Python
10.45-11.30	Data Driven Business trends and key issues (legal, standards, cyber security, ..) - evolution towards open systems (IEC-61131, IETF IP/TCP, Unix/C/Python) - data monitoring & visualization, Digital Twinning, Augmented Reality - from hardwiring (PLC) to visual programming & training of AI/Machine learning - legal issues (of machine/IoT data collection and sharing) - international standards: OPC-UA, Ethernet, TCP/IP, Admin shell
11.30-12.15	Assignment 2 – Collect I/O data from a Pi to your own computer using OPC
13.00-13.45	Cyber security - Explanation of IP/Ethernet networks and how to make them secure
13.45-14.30	Assignment 3 – Collect I/O data from an industrial PLC (RevPi+revpimodio)
15.00-15.30	Data Collection with MQTT
15.30-16.00	Assignment 4 - Secure configuration of for data collecting from Pi and Industrial PLC
16.00-end	You have worked with open source tools to collect data from shop floor & equipment, and understand how to configure and use them in a cyber secure way.

SMART INDUSTRY DUTCH INDUSTRY FIT FOR THE FUTURE

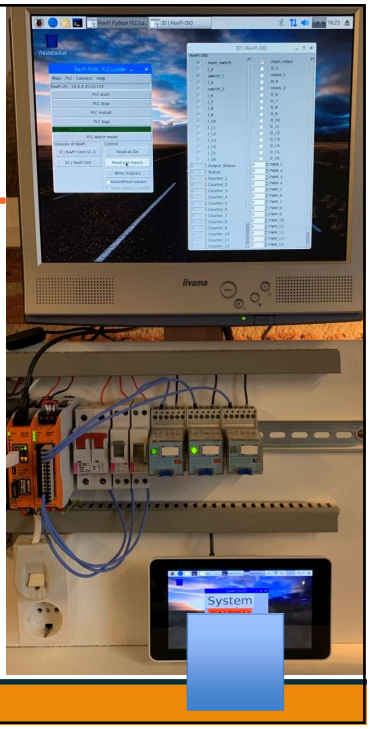
Data collection from the factory floor

An Ethernet cable plugged into a PLC ……



how about

cyber security?

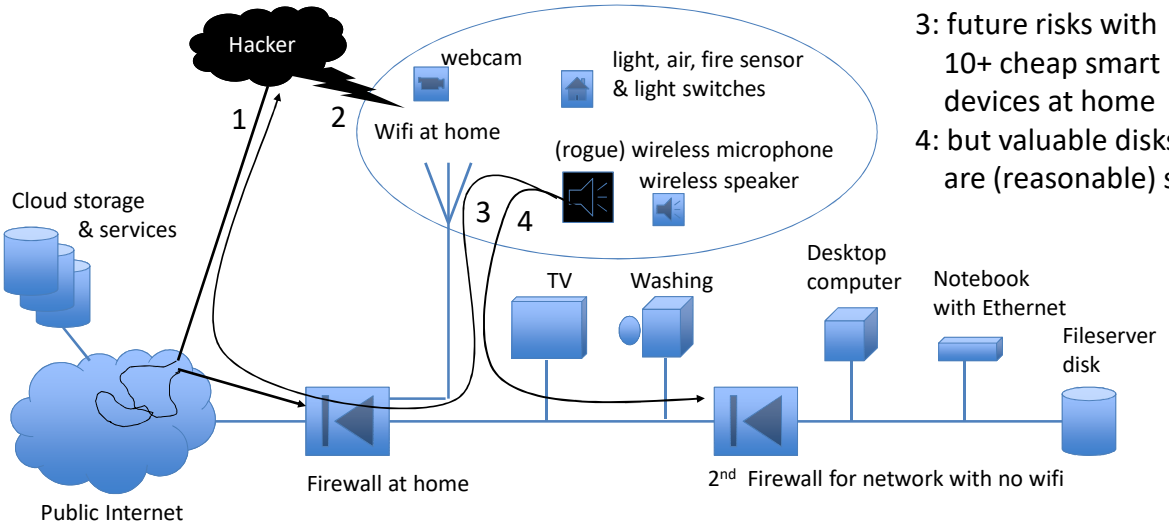


SMART INDUSTRY DUTCH INDUSTRY FIT FOR THE FUTURE

Egbert-jan.sol@tno.nl

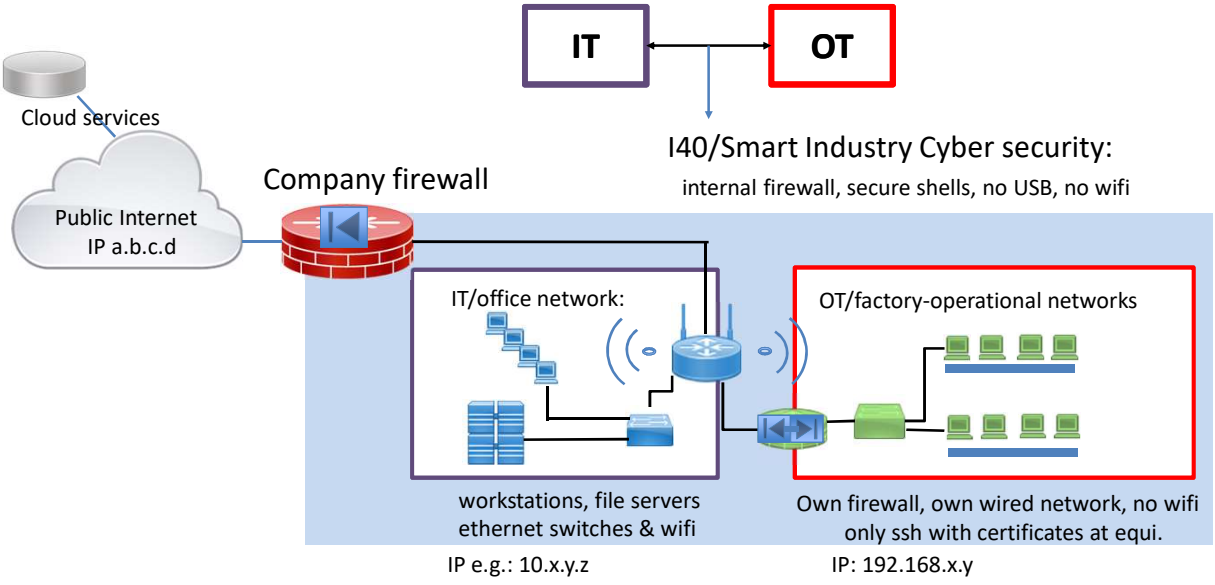
How to protect your home network

1: blocked by firewall
2: risk from streetside
3: future risks with 10+ cheap smart devices at home
4: but valuable disks are (reasonable) save



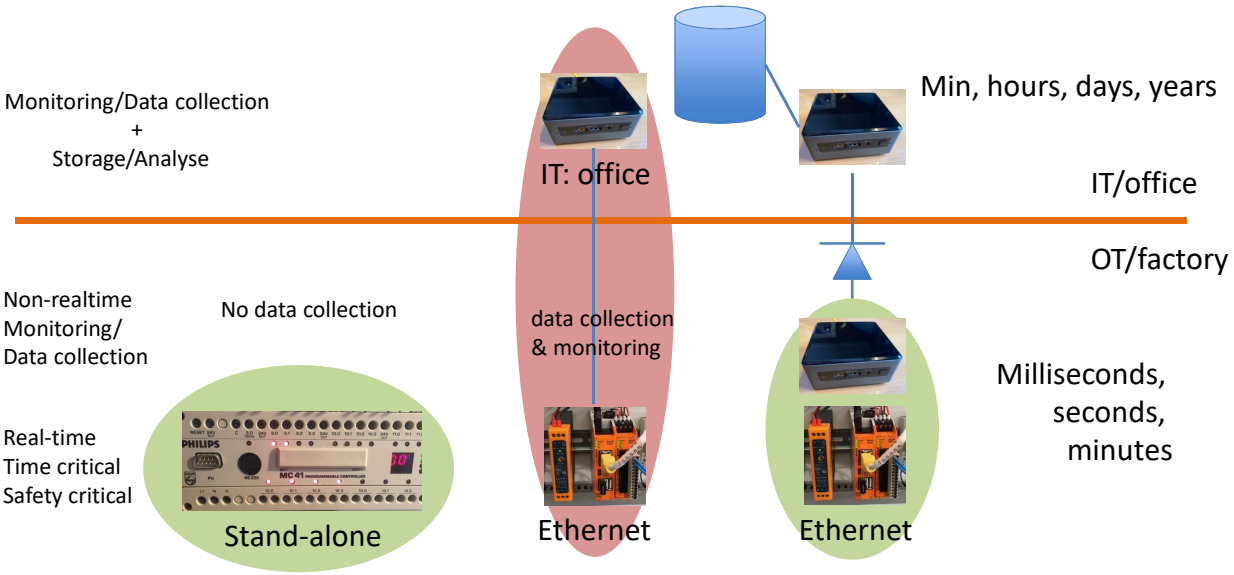
SMART INDUSTRY DUTCH INDUSTRY FIT FOR THE FUTURE

IT versus OT: Factory/equipment Network ≠ *Office*



SMART INDUSTRY DUTCH INDUSTRY FIT FOR THE FUTURE

IT versus OT: not only risks but also realtime vs non-RT



Slides from Jules on security in general and OT security in particular

SMART INDUSTRY DUTCH INDUSTRY FIT FOR THE FUTURE

Egbert-jan.sol@tno.nl

1 & 2 Recap so far and next step 3 & 4

Now you have seen some basics of open source, standard operating systems & programming
(1) Unix command line and
(2) Python, here Raspbian, Windows (LXDE)
as well as (next slide)
(3) accessing them directly and
(4) over the wifi/LAN/Internet (using ssh for command line or VNC for windows)
you learned to
(5) deal with the systems and start/stop programs
(6) and make them a little more secure

Next, we will use it for industrial data access, monitor, visualization & control programs to remotely control an open source PLC and collect its data (RevPi, MQTT, OPC-UA) and powerful open source apps to visualize data (Python and Node-Red)

Existing, 30 year old legacy system still running fine

PLC has today
No logging
No historical information
No internet interfacing,
No monitoring (except led lights)
and **no risk of cyber attack**.

AND	9.0
EQL	12.0
JFRF	17
AND	9.1
JFRF	6
EQL	12.1
EQL	12.2
EQL	12.3
ANDNT	0.1
JFRF	10
EQL	12.1
EQL	12.2
EQL	12.3
SET 1	100.0
AND	9.2
EQL	12.1
SET 1	100.0
AND	9.3
EQL	12.2
LSTIO	12
END	9

E.g. 30 year old imachine still runs fine (Philips 4-bit PLC 1988, 12 input, 8 output)
On/off switch => total machine hours (input 9.0, output on 12.0)
Test switch =>check all outputs (input 9.1, output 12.1)
Sensor on entry and exit lock (entry I/O 9.2/12.2, exit I/O 9.3/12.3)
=>time in machine, delta in-out = nr of defects

You introduce Smart Industry and want to collect factory floor data and share data, so …
how to upload data to an office PC with Excel/graphics for daily monitoring and longterm data storage?

Egbert-jan.sol@tno.nl

First open PLC standard: IEC 61131 (1993) (80-ties 1131)

1: Instruction List

```
AND     9.0
EQL     12.0
JFRF    17
AND     9.1
JFRF    6
EQL     12.1
EQL     12.2
EQL     12.3
ANDNT   0.1
JFRF    10
EQL     12.1
EQL     12.2
EQL     12.3
SET 1   100.0
AND     9.2
EQL     12.1
SET 1   100.0
AND     9.3
EQL     12.2
LSTIO   12
END     9
```

2: Strucuture Text

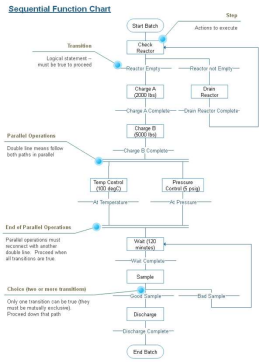
a la Pascal/Python

```
S := State(Machine)

CASE S OF
 1: closevalve();
      valvestate:=0;
 2: openvalve();
    valvestate:=1;
ELSE
    BadState();
```

3: Ladder diagrams

```
|- -[ ]- + - -[/]- - ( ) - |
|    i1   |     i3     o1   |
|- -[ ]- |                  |
     i2
```

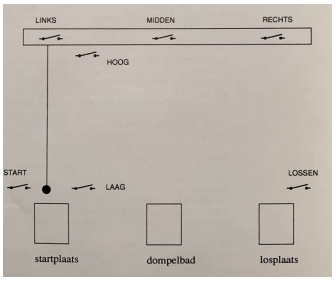
4 (FBD/SFC) Sequential Function Charts



wikipedia

Textual | Visual Programming

Our use case: towards a more data driven business



Warehouse with control temp, humidity with crane and double lock doors and 10/8 I/O PLC

Entrance 2

Door 2 Door 1

1989: (30 y) no cyber risks, no data collection but doors are controlled to avoid leakage: if one open, other is always closed

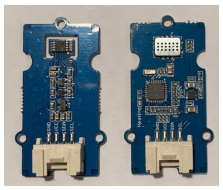
2019: open a door and close it as fast as poss. to avoid leakage (a minimize energy costs) and with temp/humi sensor log/trace of a constant atmosphere for customer proof.

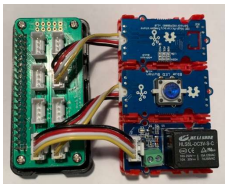
New PLC/control system with data collection,
but it should be cyber secure as you don't want a hacker (to threaten) to open both doors and destroy million of perishable goods to rot away, but allow you customer to monitor them.

Egbert-jan.sol@tno.nl

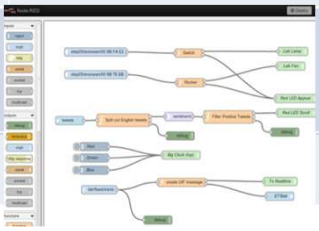
Solutions for our use case:

From cyclic PLC programming to
event driven Python computer programming



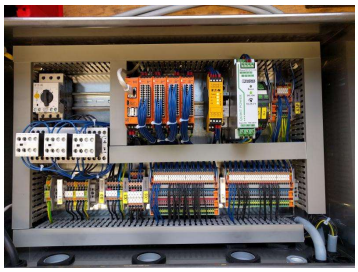


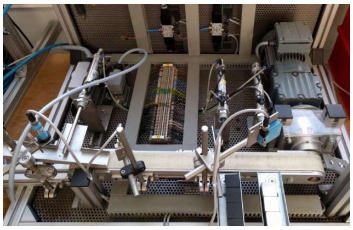
Type	example	Costs/Watt	Remarks
IoT node	e.g. Pi-Zero (10€) + Seeed/Adafruit (high accurary temp, chip sensor) 7€ (acc. temp) - 40€ (gas, temp, hum)	2 x 50 € 2 x <10 W	Wifi ? ~ethernet
Single board Open Source	RaspberryPi (Pi-3 b+) 40€ with same sensor & wired Ethernet	2 x 100 € 2 x 12 W	Large base of open source Software tools e.g. Red-node
Today's PLC Open source Or Proprietary	e.g. open source PLC from Kunbus Revolution Pi (Rasp.Pi based) Prop. PLCs from Siemens, Beckhoff, ..	500€m 25W 2-20x (1-10K)	
Old Solution	Vendor Lock-in, no data monitoring No Ethernet/Internet, no cyber risks		



SMART INDUSTRY DUTCH INDUSTRY FIT FOR THE FUTURE

Industrial control: 1 Input/1 Output to 10/1 to 100/1 IO





Yesterday's example 12/8 I/O PLC to today 100/10 – 1000/10 I/O

100+ Inputs with affordable sensors requires IT-type programming

Example in Python:
Conveyorbelt, entry point with colour detection, stops, etc.

```
def switch(self, richtung, speed):
    if self.rpi.io.notaus_ok.value and self.rpi.io.fu_frei.value:

        if self.rpi.io[richtung].value and self.rpi.io.fu_soll.value == speed:
            return True

        if self.grundstellung(self.rpi.io.fu_motoran.value):
            self.rpi.io[richtung].value = True
            self.rpi.io.fu_soll.value = speed
            return True
    else:
        self.grundstellung()
    return False
```

Pictures and code from https://revpimodio.org

SMART INDUSTRY DUTCH INDUSTRY FIT FOR THE FUTURE

Egbert-jan.sol@tno.nl

Industrial graded (24VDC) data collection

Kunbus Revolution Pi: RevPi
based on Raspberry Pi ➔

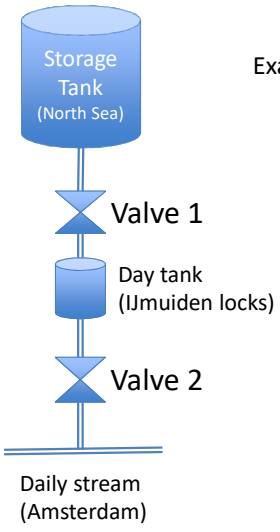
RevPi Core 3	(200 €)
14 Digital IO	(200 €)
24V Power supply + 3 x switches + 3 relays (??)	(50-100 €)
total:	500 € hardw.
	0 € softw.
	manhours ?

RevPi: hardware
- local: HDMI screen, USB keyboard+mouse
- network: Ethernet/IP (remote login SSH, ….)

RevPi: software (all open source)
- OS: Raspbian with realtime adaption, open source, based upon Unix Debian
- App: Programmable in Python, C and IEC 61131 (PLC language)
  - e.g. RevPiModio (revpipyload (on RevPi) and revpipycontrol (on PC Windows/Unix, ..

www.evolution.kunbus.de , www.revpimodio.org / pi@RevPi ~/ $ sudo apt-get install python3-revpimodio2

Very simple Industrial (PLC) Control example



Example: fill tank for one day production (fuel, sea-lock)

3 on/off inputs: main switch, switch_1 (valve 1) & 2 (valve 2)
2 relay valve A & B: output relais_1 & relais_2
- If main == On
  - If A then not B
  - If B then not A

Security issue: A and B should never be open at the same time: risk of flooding

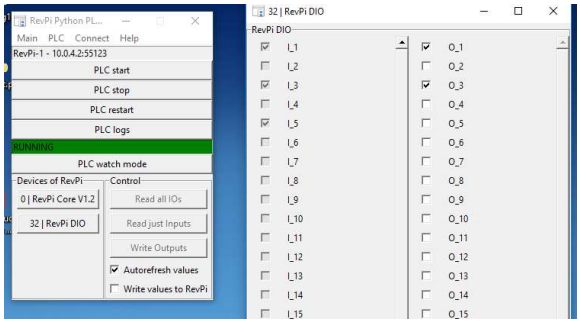
Industrial control versus Office environment: RealTime/critical vs non-RT

Realtime (classical) PLC programming with cycle loop (50 msec)
or embedded systems programming with (realtime) events in C/Python

Egbert-jan.sol@tno.nl

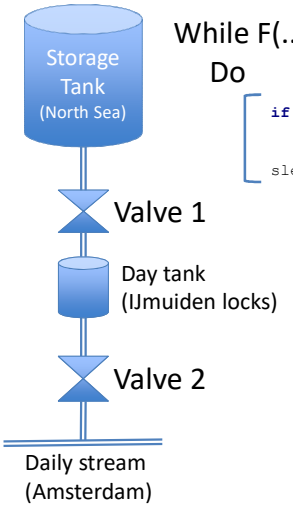
Open Source/Industrial Grade Monitoring & Controlling

3 input/2 output
On/Off and two
Motor relays A, B
If A then not B
If B then not A



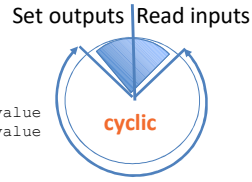

```
Cyclic version …..

if not (self.rpi.io.switch_1.value and self.rpi.io.switch_2) :
    self.rpi.io.valve_1.value = self.rpi.io.switch_main.value and self.rpi.io.switch_1.value and not self.rpi.io.switch_2.value
    self.rpi.io.valve_2.value = self.rpi.io.switch_main.value and self.rpi.io.switch_2.value and not self.rpi.io.switch_1.value

Or event_driven version …..
Def event_switch_1_on(self, ioname, iovalue):
          if self.main_state and not self.state_2_on:
                    self.rpi.io.valve_1.value = True
                    self.state_1_on = True
```


Industrial (PLC) Control (2/4) - cyclic versus event driven



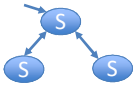
While F(..) = True
Do

```
if not (switch_1.value and switch_2.value) :
    valve_1.value = switch_main.value and switch_1.value and not switch_2.value
    valve_2.value = switch_main.value and switch_1.value and not switch_1.value
sleep(0,00x)
```



Process while-do

event driven programming

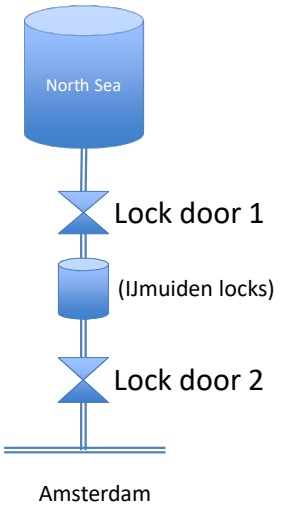


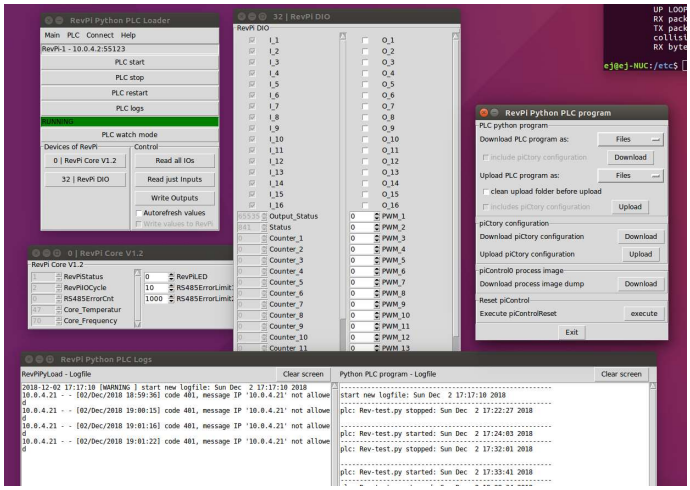

```
switch_1.reg_event(event_switch_1_on, edge=RISING)
…..
def event_switch_1_on()
          if main_state and not state_2_on:
                    valve_1.value = True
                    state_1_on = True

+ 5 other event_handlers
```

Register events & define states
then program (event_)handlers

Egbert-jan.sol@tno.nl

Demo – controlling the PLC over the internet – wrecking it

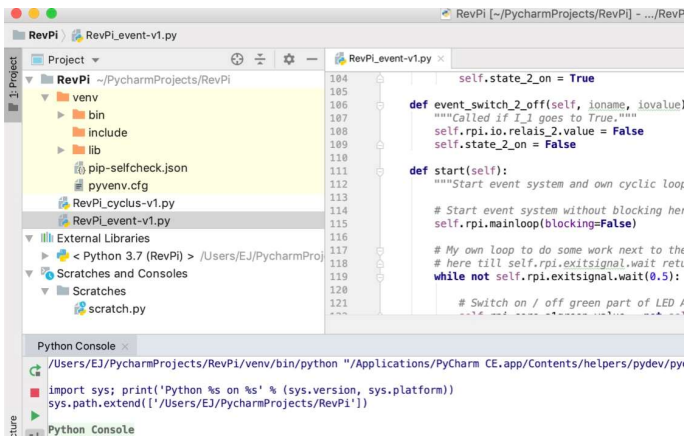


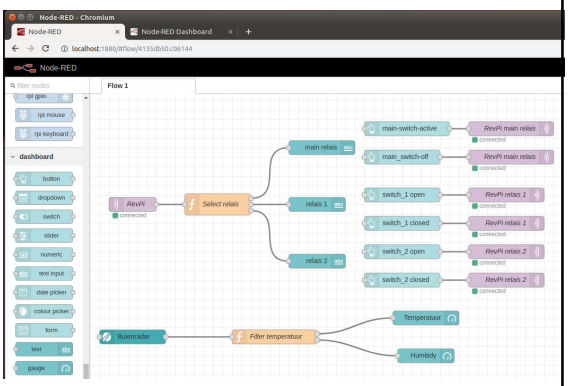


Industrial (PLC) Control - event programming (e.g. Python) or visual programming (using open source Node-Red)

Python – (OOP object oriented) event programming

Node-Red – visual programming





Egbert-jan.sol@tno.nl

Assignment 3

13.45-14.30 Demo/Groupwork 3 – Data collection from an industrial PLC (RevPi+revpimodio)

Assignment 3:

MQTT.fx (from www.mqttfx.org , it is a Java program, so you need to run java too from www.java.com)

And for latter access to the Revolution PLC Pi (RevPI) you can also download
the RevPi control program revpipycontrol_0.7.1.exe (also LGPLv3 open source)

https://revpimodio.org/en/sources/revpipycontrol/

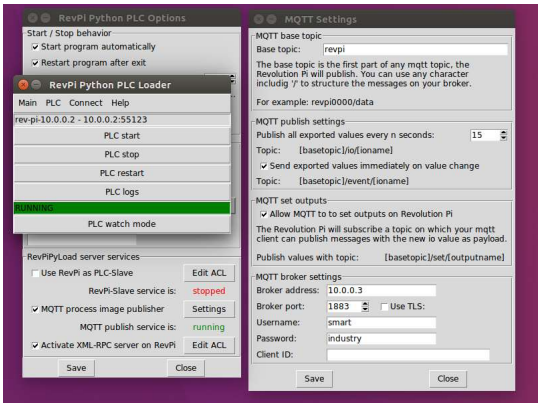
3 data acquisition MQTT/mosquitto (or OPC-UA assign 4)

The RevPi with Revpipyload also works with MQTT/Mosquitto for data acquisition
(a pity does not run OPC-UA on RevPi-core1, but should run on a core-3 & Pi-3 b+)

MQTT is an international standard
(good info at Youtube at e.g.
http://www.steves-internet-guide.com/

```
For more details see more(1).
pi@Rev-ej:/etc/revpipyload $ more +/MQTT revpipyload.conf

...skipping
bindip = *

[MQTT]
mqtt = 1
basetopic = revpi
sendinterval = 15
send_on_event = 1
write_outputs = 0
broker_address = 10.0.0.3
port = 1883
tls_set = 0
username = smart
password = industry
client_id =
```

Settings on the RevPi



Egbert-jan.sol@tno.nl

3 remote login, monitor and control of the RevolutionPi

From your own computer run the program revpipycontrol.exe

Revpipycontrol (from https://revpimodio.org/dnl/revpipycontrol_0.7.1.exe)

main (1st menu), connections, revpi 10.0.0.2 on port 55123, save,
then connect (3rd menu), revpi,

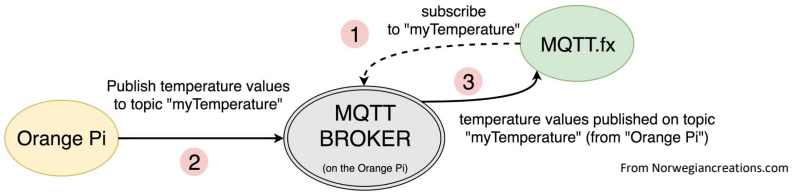
PLC (2nd menu), PLC watch mode, 32|RevPi DIO, read all I/O's
PLC (2nd menu), PL C program, download to your own pc, e.g. desktop
and then open RevPi_event-v1.py file (e.g. with word) and have a look at it.

exit subwindows of PLC download and go to 32|RevPi DIO en select main_relais,
then to main RevPi Python PLC windows, write Outputs (yes). One click, but nothing?
again in main RevPi Python PLC windows, PLC stop and write output again,
and for the fun part select also relais-1, and -2. and write output again.

MQTT: data collection from sensor/low-cost devices

Simple lightweight protocol: not much bandwidth and (energy) efficient

And very low cost with Pi's and 3.3/5V sensors open source software

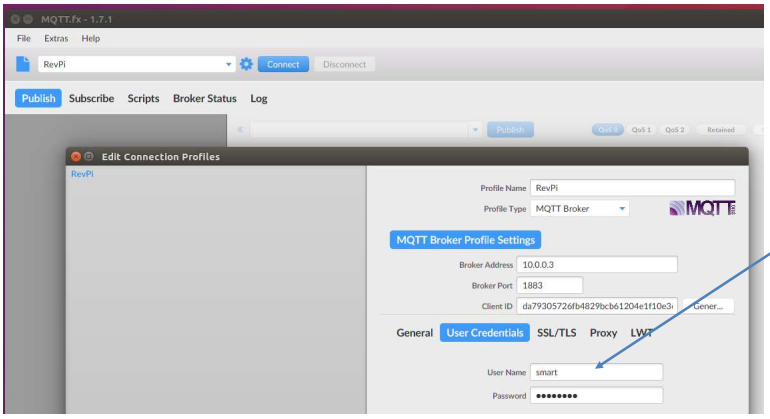


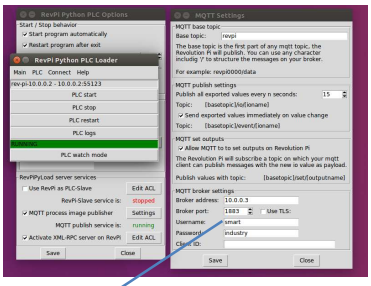
0: Launch an MQTT broker on a machine (IP address, port 1833) (MQTT sits on top of TCP)
(e.g. on a Pi 3 with mosquitto and paho-mqtt)
1: Launch an subscriber process with connects to MQTT broker on IP:1833
and subscribes to a name: e.g. myTemperature
(e.g. on a PC/Mac with MQTT.fx (.exe or .app file) with MQTT.fx in java)
2: Launch on sensor device (e.g. Pi or Rev) an publisher, connect to broker on IP:1833
and start publishing myTemperature
(e.g. on same Pi 3 with mosquito in python: mqtt.client.publish(myTemperature, t))
3: watch MQTT.fx windows for temperature values
or use an Microsoft Azure IoT .exe or an AWS packages instead of MQTT.fx
or open-source Node-RED for visualisation

Egbert-jan.sol@tno.nl

3 MQTT data acquisition from RevolutionPi to Windows PC

Run MQTT.fx (an open source Java) MQTT browser
First Connect with setting from RevPi (PLC or Load),
fill in your IP number and enter username/password



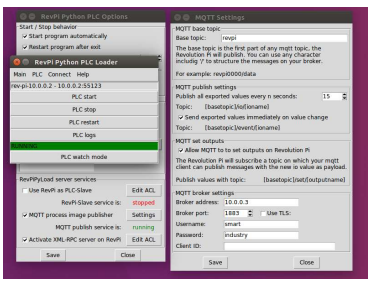


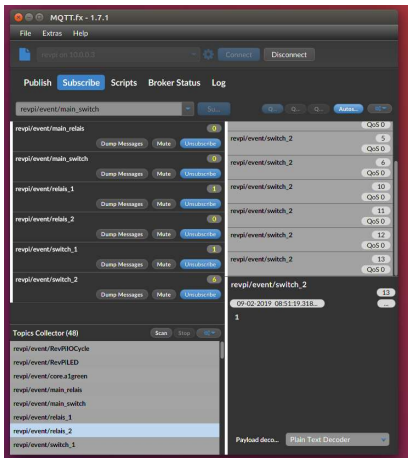
SMART INDUSTRY DUTCH INDUSTRY FIT FOR THE FUTURE

3 MQTT data acquisition from RevolutionPi on Windows PC

Run MQTT.fx (an open source Java) MQTT browser

After Connect, goto subscribe and scan in topics collector
double click on parameters of interest
(e.g. revpi/event/switch_1)
click on it an monitor them





SMART INDUSTRY DUTCH INDUSTRY FIT FOR THE FUTURE

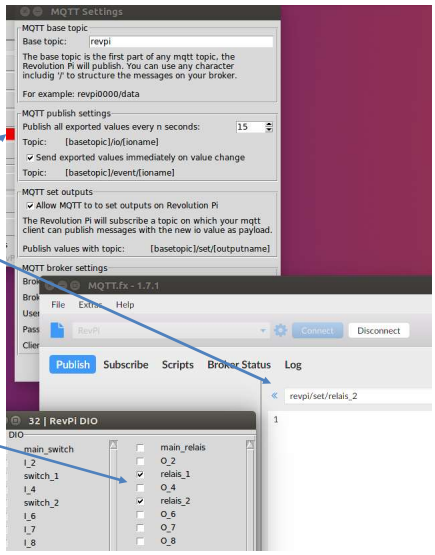
Egbert-jan.sol@tno.nl

3 MQTT data acquisition from RevolutionPi on Windows PC

And with MQTT.fx (an open source Java) you can set outputs with publish too

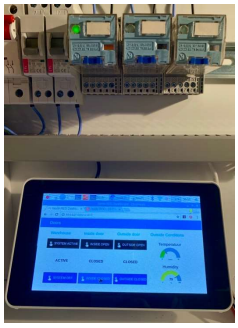
Note: use revpi/set/relais_2 with value 1
not revpi/io/relais_2

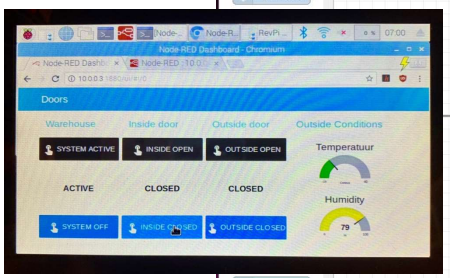
If the program on the RevPi has been stopped, You can open both doors



3 data acquisition using https://nodered.org from RevolutionPi

Instead of Python programming, you can use visual programming with Node-Red, standard on a Pi





If RevPi runs, it over runs Node-RED
but if RevPi program stops, ……

Egbert-jan.sol@tno.nl

3 data acquisition using Python from the RevolutionPi

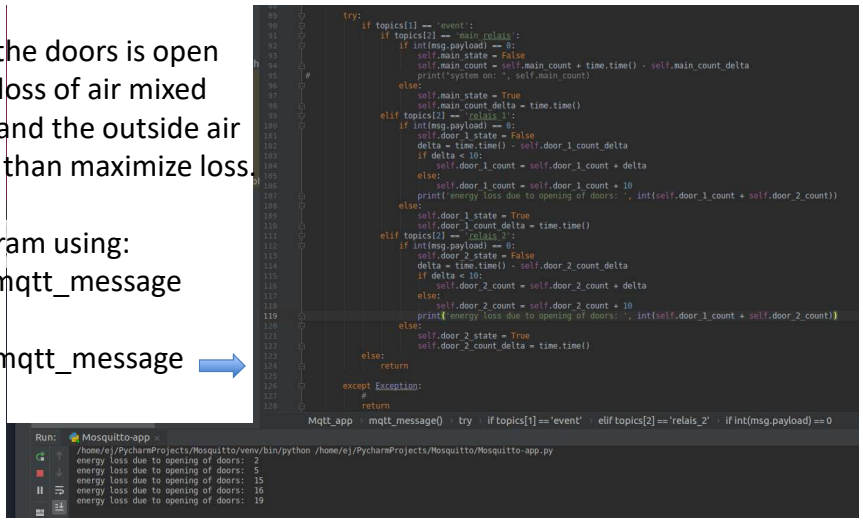
Monitor the time one of the doors is open and calculate the energy loss of air mixed between the warehouse and the outside air
Ps. If door open > 10 sec, than maximize loss.

Event driver Python program using:
Mqtt.on_message – self.mqtt_message

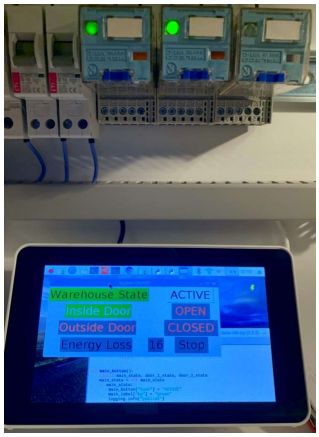
Shown is key part of self.mqtt_message

and results:

2-8 hours work



3 data acquisition using Python and

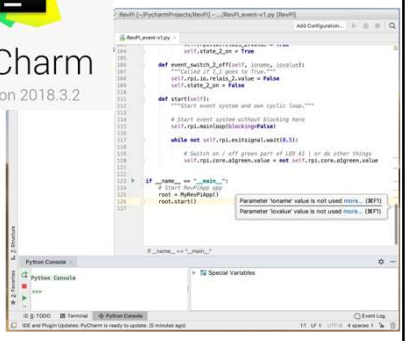


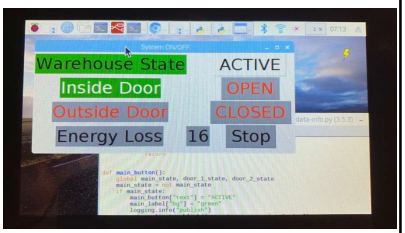
Controlling the RevPi warehouse system using Python program from an Pi using Pycharm as IDE an Paho for MQTT as from: (http://www.steves-internet-guide.com)

Challenge: next to door control,
collect data on door open times
to give feedback to minimize
energy loss and lower energy costs

Energy loss:
daily sum of heat leakage every time
the inside/outside doors are opened.

PyCharm
Version 2018.3.2





If RevPi internal PLC program runs, it over runs the remote control by MQTT
Once RevPi program stops, remote control and remote hacking is possible.

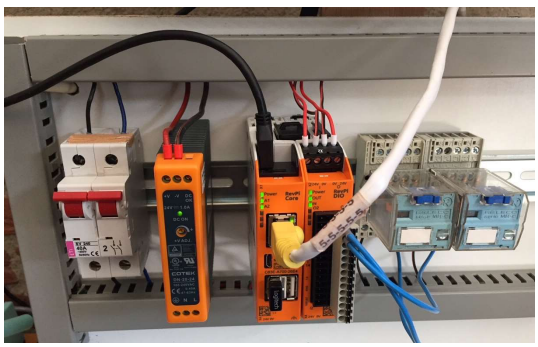
Egbert-jan.sol@tno.nl

Program

09.30-10.00	Intro with data collection & cyber security on the factory floor and from equipment shop floor example and training course equivalent with Raspberry Pi
10.00-10.30	Assignment 1 – Get remote access to your Pi from own notebook and try Python
10.45-11.30	Data Driven Business trends and key issues (legal, standards, cyber security, ..) - evolution towards open systems (IEC-61131, IETF IP/TCP, Unix/C/Python) - data monitoring & visualization, Digital Twinning, Augmented Reality - from hardwiring (PLC) to visual programming & training of AI/Machine learning - legal issues (of machine/IoT data collection and sharing) - international standards: OPC-UA, Ethernet, TCP/IP, Admin shell
11.30-12.15	Assignment 2 – Collect I/O data from a Pi to your own computer using OPC
13.00-13.45	Cyber security - Explanation of IP/Ethernet networks and how to make them secure
13.45-14.30	Assignment 3 – Collect I/O data from an industrial PLC (RevPi+revpimodio)
15.00-15.30	Data Collection with MQTT
15.30-16.00	Assignment 4 - Secure configuration of for data collecting from Pi and Industrial PLC
16.00-end	You have worked with open source tools to collect data from shop floor & equipment, and understand how to configure and use them in a cyber secure way.

Data collection from the factory floor

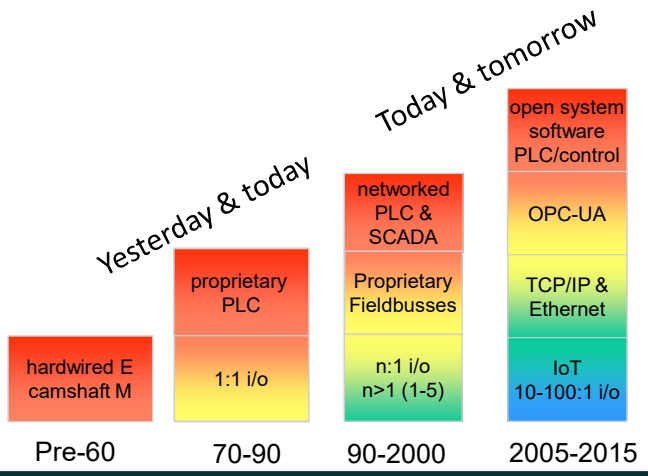
An Ethernet cable plugged into a PLC ……



Egbert-jan.sol@tno.nl

Summary of the day: The need for more digital skills

Operation (education, maintenance, legal) issues



Visual and textual (Python/C) programming environments

Object & XML description

Digital Twin/
Digital Identification
Admin Shell

Cyber security in OT-domain is different from IT (office)

Program

13.00-14.30	Introduction industrial revolutions, productivity, people scarcity & lifelong learning challenge data use + demo warehouse control hooking up sensors/equipment/PLC to the Internet …. Bang.
14.30-15.15	Data on the Factory Floor from classical PLC with 1/1 IO and cycle loop to 10-100/1 I/O and event program. from very technical to legal & business issues
15.15-15.30	Break
15.30-16.00	OPC standard, other standards & cyber security
16.00-16.30	Demonstration using open source PLC, software, etc.
16.30-end	Conclusion & Closure

Egbert-jan.sol@tno.nl

Assignment 4

15.30-16.00 Groupwork 4 - More secure configuration of training Pi and Industrial Pi

Egbert-jan.sol@tno.nl