APPENDIX B

SOLUTION EXERCISES STEP BY STEP

An appendix to the thesis submitted in partial
fulfillment of the requirement for the award of the
Bachelor's Degree of Mechanical Engineering with Honours

Faculty of Mechanical and Manufacturing Engineering
Universiti Tun Hussein Onn Malaysia

JULY 2023

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Abstract

This document is an English explanation on how to solve the Learning Factory. Each of the exercises has a chapter where answers are provided step by step. Solutions are provided in the following format: On the left-hand side figures show illustrate the steps. On the right-hand side the reader can find instructions.

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CHAPTER 1

Glossary

German	**English**
Lern	Learn
Fabrik	Factory
Lernfabrik	Learning factory
Aktuell	Current
Künstliche Intelligenz / KI	Artificial Intelligence / AI
Modul	Module
Modell	Model

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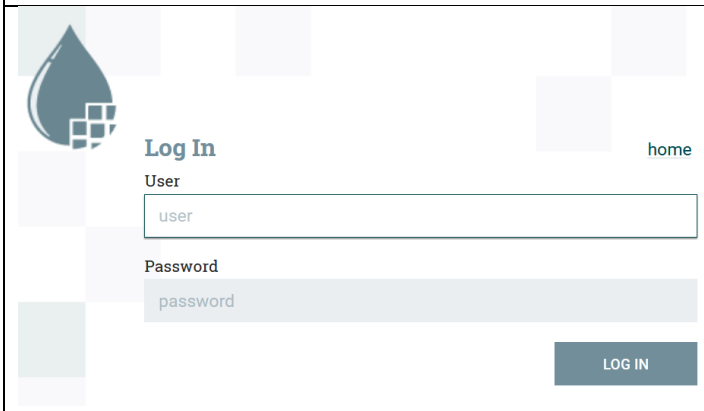
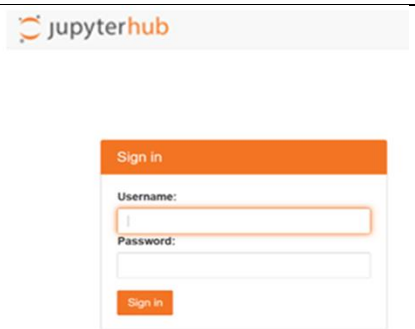
CHAPTER 2

Exercise 1

hivemqserver.feste-ip.net:9443/nifi/	Open link to nifi page
	Insert the following credentials: user: lernfabrik pw: L5nf1br|k Now you can take a look
hivemqserver.feste-ip.net:9001	Open the link to access Jupyter
	Insert the following credentials: user: lernfabrik pw: L5nf1br|k From here you can open new terminals and view the used notebooks
hivemqserver.feste-ip.net:1880	Open the link to access Node-RED online tool

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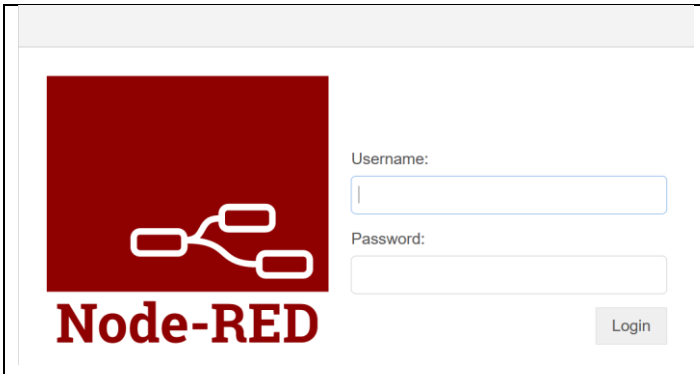	Insert the following credentials: user: lernfabrik pw: L5nf1br|k This tool establishes the communication to the factory

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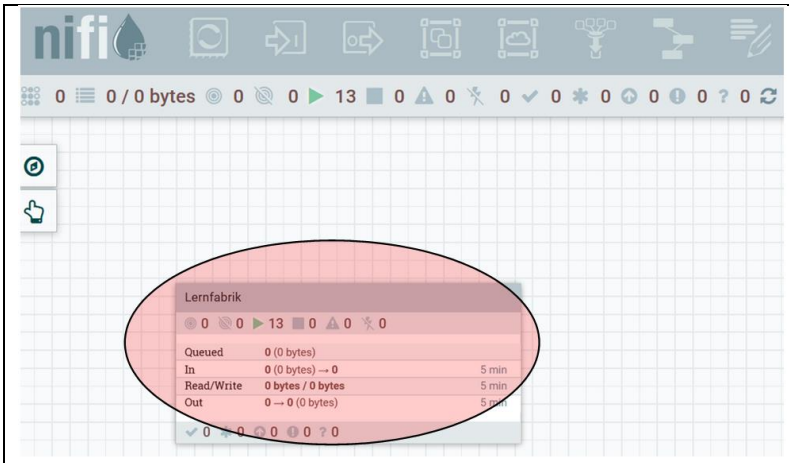
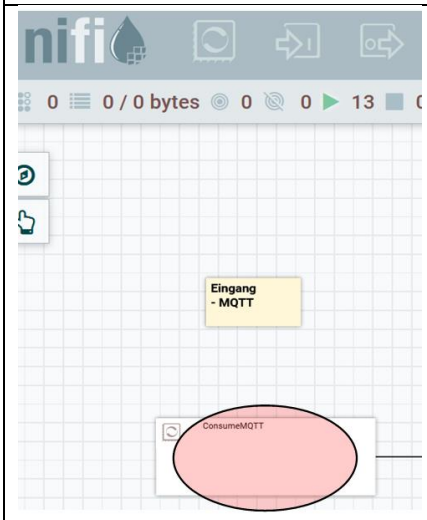
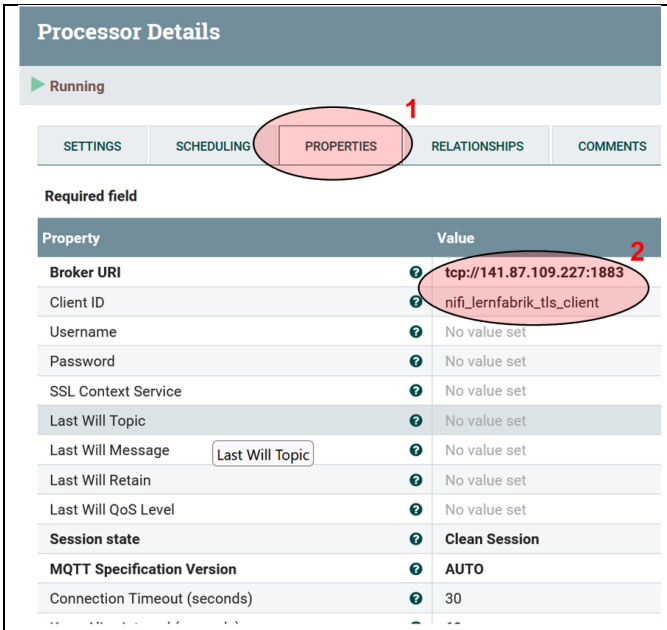
CHAPTER 3

Exercise 2

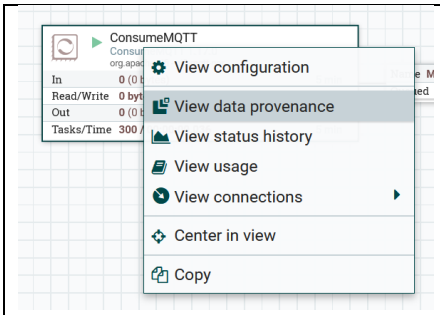
a)

	Double Click
	Click

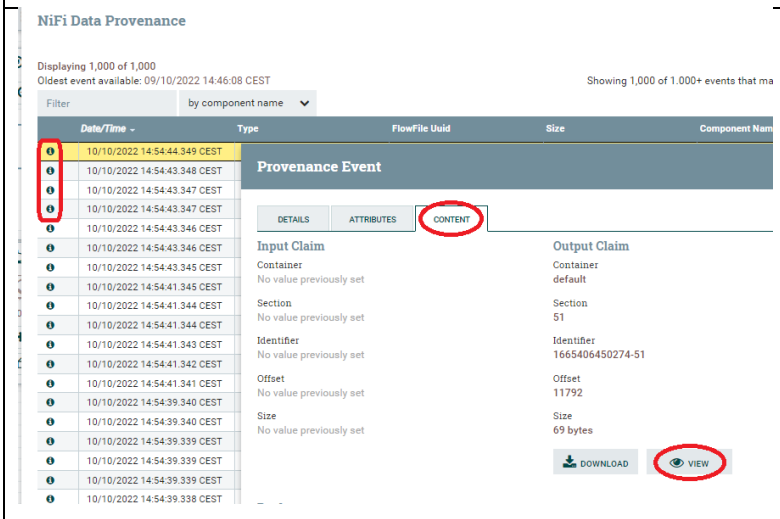


1) Click
2) Read

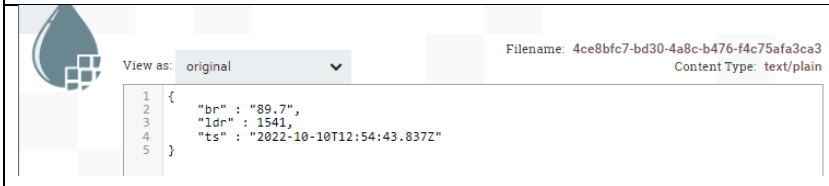
b)



1) Right Tap on Consume MQTT
2) Tap View data provenance



1) Click the info symbol of the message you are interested
2) Tap Content
3) Tap View

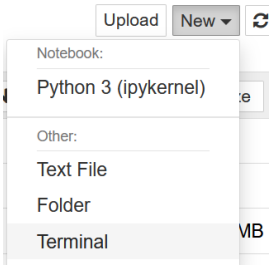


Complete MQTT-Message

CHAPTER 4

Exercise 3

a)

	1) Click new 2) Click terminal

jupyterhub
`lernfabrik@hivemqserver:~$ cd cli-client/`
`lernfabrik@hivemqserver:~/cli-client$ python3 lernfabrik.py -o BLUE`
	Type into terminal
	1) Go to directory
	2) Execute order

`Es wird ein Werkstück mit der Farbe "BLUE" bestellt.`
 	
`Connected to broker via TCP`
`Vorgang war erfolgreich!`
 	
A workpiece with color “BLUE” has been ordered.
Connected to broker via TCP.
Process was successful.
	Answer of terminal

b)

`lernfabrik@hivemqserver:~/cli-client$ python3 lernfabrik.py -f`	Type
`Aktueller Fabrikstatus: ORDERED` Current factory state: ORDERED	Response of terminal

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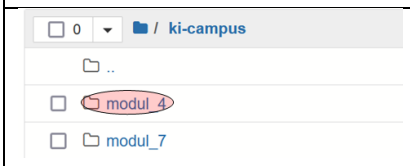
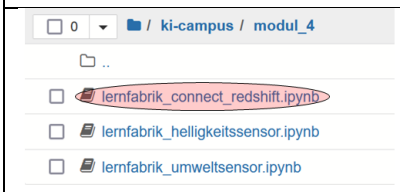
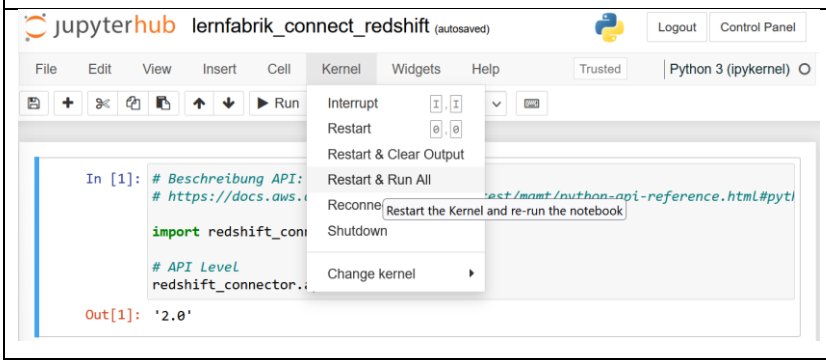
CHAPTER 5

Exercise 4

	1) Open JupyterHub 2) Double click ki-campus folder
	Double click modul_4 folder
	Open notebook by double click
	Execute the notebook by clicking Restart & Run All

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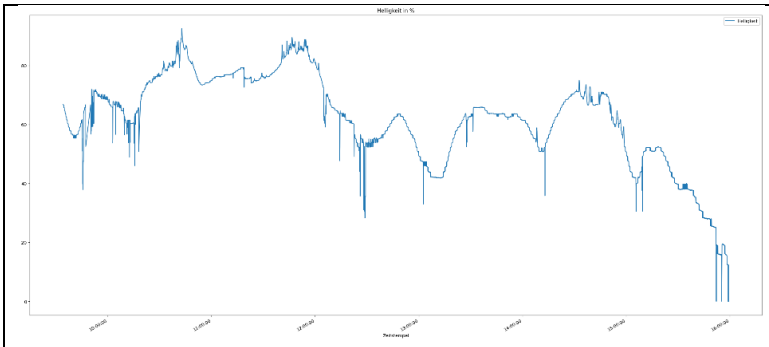
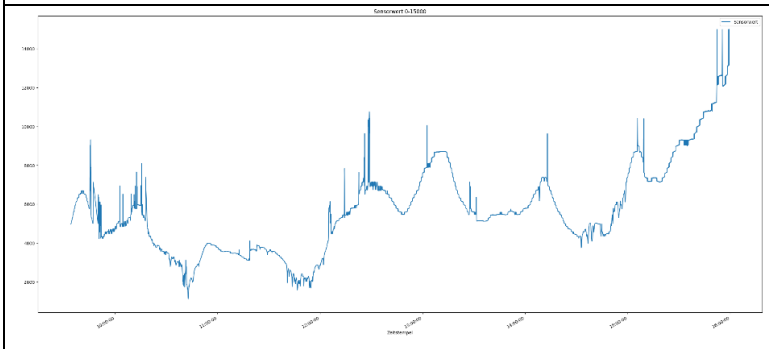
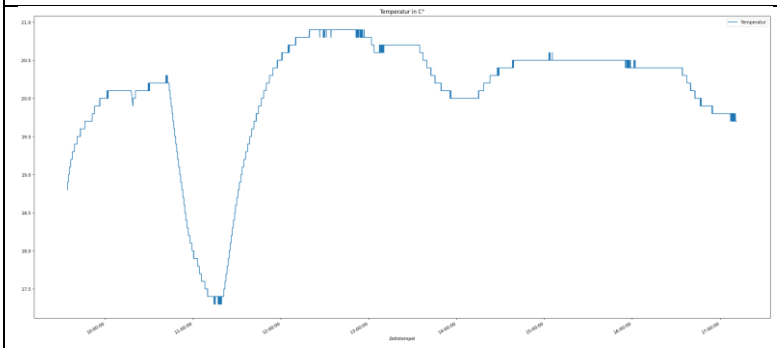
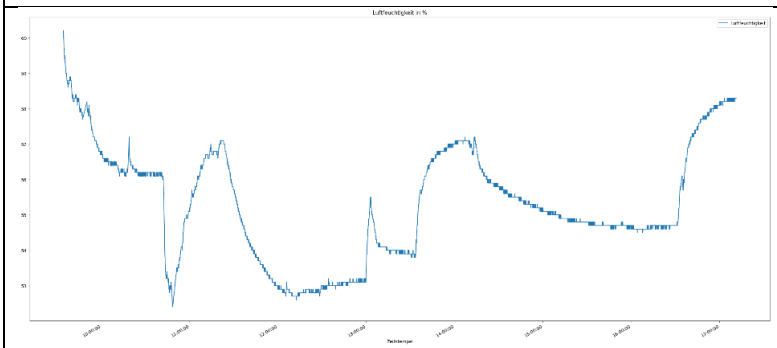
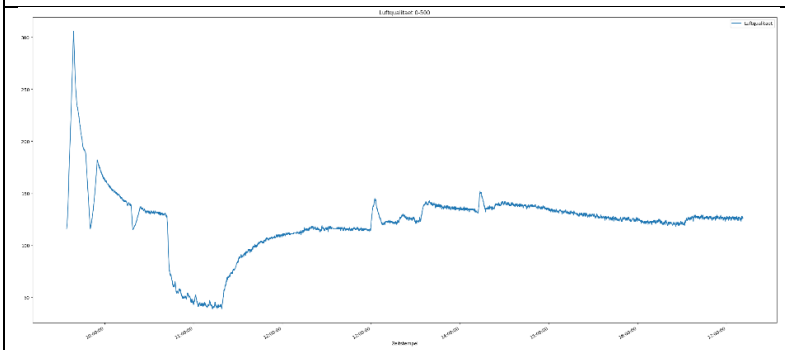
	Brightness in % is sinkings
	Brightness sensor value is increasing
	Temperature in °C is increasing in the beginning, then falling and increasing rapidly and changing slightly in the end
	Humidity is falling in the beginning, then rising and falling over the time
	Air quality value is decreasing in the beginning, then rising softly towards an asymptote

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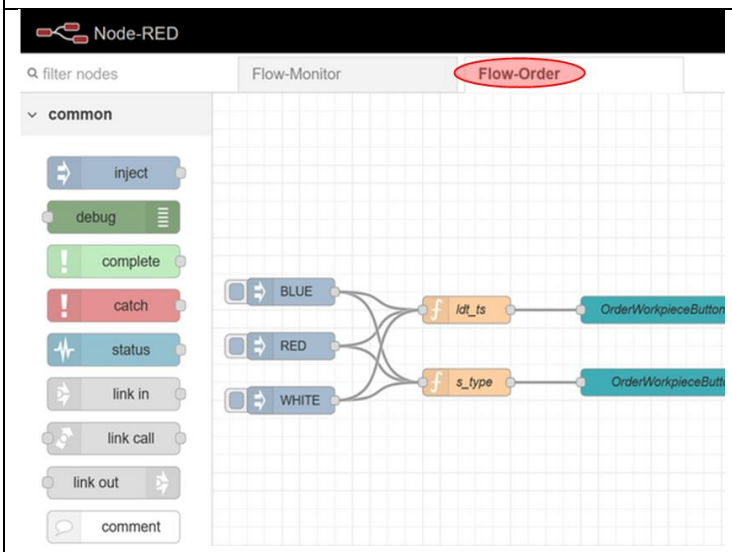
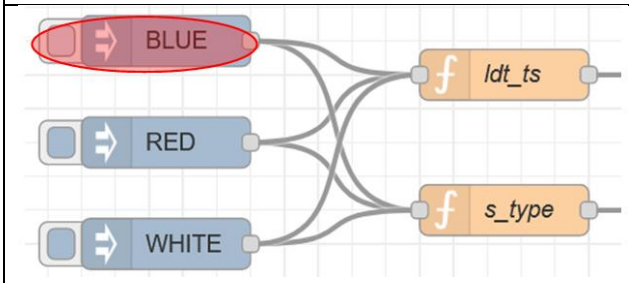
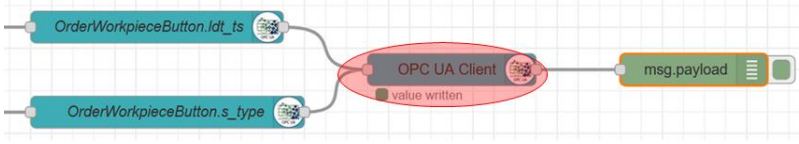
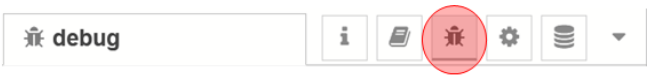
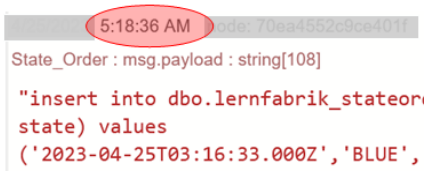
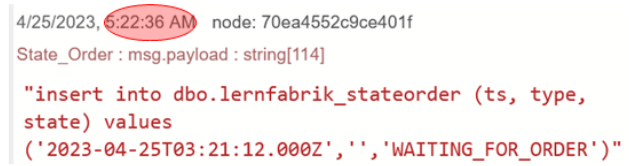
CHAPTER 6

Exercise 5

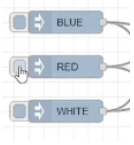
a)

Open Node RED, sign in	
	Click on Flow order to reach the flow, that is used to control the factory
	
	OPC UA Client node should show “value written”

b)

Trigger order like shown in a)	
	In the upper right corner, click on the bug to open the debug feed
	Wait for confirmation that a order has been placed Read the time the order has been placed: 5:18,36AM
	Wait during messages that show “IN_PROCESS” and “SHIPPED”
	Read the time in the message showing “WAITING_FOR_ORDER”: 5:22,36AM
5:22,36AM - 5:18,36AM = 4min	Calculate the duration

c)

-Trigger the same process like in b) -Goal of this task is to understand the messages issued in the debug window	
	Order triggered for red piece
5.7.2022, 18:32:00 node: 70ea4552c9ce401f State_Order : msg.payload : string[107] "insert into dbo.lernfabrik_stateorder (ts, type, state) values ('2022-07-05T16:31:56.000Z','RED','ORDERED')"	Confirmation that red piece is ordered
5.7.2022, 18:32:30 node: a1c7c907efb05359 Stock_HBW : msg.payload : string[555] "insert into dbo.lernfabrik_hbw (ts, a1_id, a1_state, a1_type, a2_id, a2_state, a2_type, a3_id, a3_state, a3_type, b1_id, b1_state, b1_type, b2_id, b2_state, b2_type, b3_id, b3_state, b3_type, c1_id, c1_state, c1_type, c2_id, c2_state, c2_type, c3_id, c3_state, c3_type) values ('2022-07-05T16:32:25.000Z','043d57a2186580','RAW','WHITE','','','','045b56a2186580','RAW','RED','045e55a2186580','RAW','RED','044057a2186580','RAW','WHITE','045259a2186580','RAW','BLUE','046c59a2186580','RAW','BLUE','046c57a2186580','RAW','WHITE','045159a2186580','RAW','BLUE')"	- This section shows the current stock - Every container has the following attributes: RFID, state if raw or already worked on and colour - Courser shows an empty space, the space is empty because of the placed order
5.7.2022, 18:33:00 node: 8ee6d72fada7f31a State_Stations : msg.payload : string[400] "insert into dbo.lernfabrik_stationen (ts, station, code, description, target, active) values ('2022-07-05T16:32:55.000Z','dsi',1,'','','false'), ('2022-07-05T16:32:55.000Z','dso',1,'','','false'), ('2022-07-05T16:32:55.000Z','hbw',2,'','','false'), ('2022-07-05T16:32:55.000Z','mpo',2,'','','false'), ('2022-07-05T16:32:55.000Z','sld',1,'','','false'), ('2022-07-05T16:32:55.000Z','vgr',2,'','mpo','true')"	- This section shows the states of each production step - The second column show the name of each station - The courser is pointing on the column indicating the state of each station 1: Ready 2: Currently working - The last column is indicating the station where the workpiece is at
5.7.2022, 18:35:00 node: 70ea4552c9ce401f State_Order : msg.payload : string[107] "insert into dbo.lernfabrik_stateorder (ts, type, state) values ('2022-07-05T16:34:42.000Z','RED','SHIPPED')"	Indicates that production is finished

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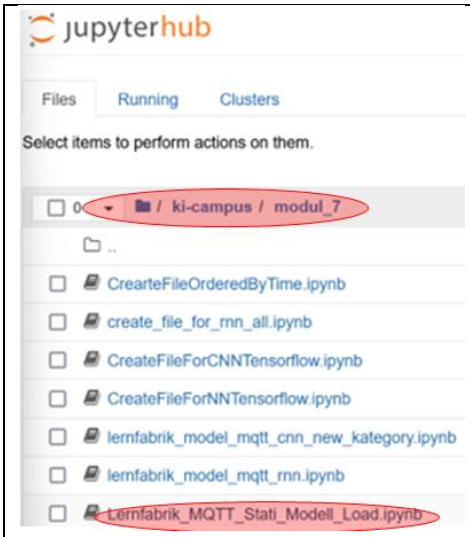
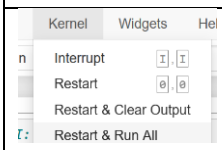
5.7.2022, 18:36:50 node: a1c7c907efb05359 Stock_HBW : msg.payload : string[575] "insert into dbo.lernfabrik_hbw (ts, a1_id, a1_state, a1_type, a2_id, a2_state, a2_type, a3_id, a3_state, a3_type, b1_id, b1_state, b1_type, b2_id, b2_state, b2_type, b3_id, b3_state, b3_type, c1_id, c1_state, c1_type, c2_id, c2_state, c2_type, c3_id, c3_state, c3_type) values ('2022-07-05T16:36:35.000Z','043d57a2186580','RAW','WHITE','04a056a2186580','RAW','RED','045b56a2186580','RAW','RED','045e55a2186580','RAW','RED','044057a2186580','RAW','WHITE','045259a2186580','RAW','BLUE','046c59a2186580','RAW','BLUE','046c57a2186580','RAW','WHITE','045159a2186580','RAW','BLUE')"	High rack storage has no empty slots anymore

Abbreviation table for stations

Delivery **S**tation **I**nput	**dsi**
Delivery **S**tation **O**utput	**dso**
High-**B**ay **W**arehouse	**hbw**
Multi **P**rocessing Station with **O**ven	**mpo**
Sorting **L**ine with Color **D**etection	**sld**
Vacuum **G**ripper **R**obot	**vgr**

CHAPTER 7

Exercise 7

	1) Navigate to modul_7 folder in jupyter 2) Open the marked notebook
	Execute the notebook by clicking Restart & Run All
Neue Message mit Topic: f/s/state/hbw 1/1 [==============================] - 0s 58ms/step aktualisierte Datenreihe [0 1 0 1 0 0 1 0 1 0 1 0 1] ergibt den Zustand: Ruhend New Message with topic: f/s/state/hbw 1/1 [==============================] - 0s 58ms/step Actualized series of data [0 1 0 1 0 0 1 0 1 0 1 0 1] results in state: Neutral	- Scroll down to the end of the script until the message on the left - It says that the factory is currently resting

	Open a new terminal and navigate to cli-client folder
python3 lernfabrik.py -o BLUE	Insert the text on the left, this will trigger the order of a blue piece
Neue Message mit Topic: f/s/state/hbw current threads = 9 1/1 [==============================] - 0s 56ms/step aktualisierte Datenreihe [0 2 0 1 0 0 1 0 1 0 1 0 1] ergibt den Zustand: Ein-/Auslagerung New Message with topic: f/s/state/hbw current threads = 9 1/1 [==============================] - 0s 56ms/step Actualized series of data [0 2 0 1 0 0 1 0 1 0 1 0 1] results in state: to (take out of) warehouse	- Go back to the notebook - Wait for new messages to show up - "Ein-/Auslagerung" means that the production process has begun as a workpieces is taken out of the warehouse
Comment: A series of messages will pop up, as a data query is send periodically. It is possible that single messages show a wrong state which can be ignored.	
Neue Message mit Topic: f/s/state/hbw 1/1 [==============================] - 0s 72ms/step aktualisierte Datenreihe [1 1 0 2 0 0 1 0 1 0 1 0 1] ergibt den Zustand: Transport New Message with topic: f/s/state/hbw 1/1 [==============================] - 0s 72ms/step Actualized series of data [1 1 0 2 0 0 1 0 1 0 1 0 1] results in state: Transport	Next message will indicate that the gripper station is now running
Neue Message mit Topic: f/s/state/hbw 1/1 [==============================] - 0s 76ms/step aktualisierte Datenreihe [0 2 0 2 0 0 2 0 1 0 1 0 1] ergibt den Zustand: Bearbeitung New Message with topic: f/s/state/hbw 1/1 [==============================] - 0s 76ms/step Actualized series of data [0 2 0 2 0 0 2 0 1 0 1 0 1] results in state: Workmanship	This message indicates that the workpiece is worked on
Neue Message mit Topic: f/s/state/hbw 1/1 [==============================] - 0s 59ms/step aktualisierte Datenreihe [0 1 0 1 0 0 1 1 2 0 1 0 1] ergibt den Zustand: Sortierung New Message with topic: f/s/state/hbw 1/1 [==============================] - 0s 59ms/step Actualized series of data [0 1 0 1 0 0 1 1 2 0 1 0 1] results in state: Sorting	This message indicates that the colour sorting process is running
Neue Message mit Topic: f/s/state/hbw 1/1 [==============================] - 0s 55ms/step aktualisierte Datenreihe [0 1 1 2 3 0 1 0 1 0 1 0 1] ergibt den Zustand: TransportToDSO New Message with topic: f/s/state/hbw 1/1 [==============================] - 0s 55ms/step Actualized series of data [0 1 1 2 3 0 1 0 1 0 1 0 1]	This message indicates that the workpiece is transferred to the output station

results in state: TransportToDSO	
Neue Message mit Topic: f/s/state/hbw 1/1 [==============================] - 0s 67ms/step aktualisierte Datenreihe [0 2 1 2 2 0 1 0 1 1 0 0 1] ergibt den Zustand: TransportToHBW New Message with topic: f/s/state/hbw 1/1 [==============================] - 0s 67ms/step Actualized series of data [0 2 1 2 2 0 1 0 1 1 0 0 1] results in state: TransportToHBW	This message indicates that the workpiece is transported back to the warehouse
Neue Message mit Topic: f/s/state/hbw 1/1 [==============================] - 0s 59ms/step aktualisierte Datenreihe [1 2 0 2 0 0 1 0 1 0 1 0 1] ergibt den Zustand: Ein-/Auslagerung New Message with topic: f/s/state/hbw 1/1 [==============================] - 0s 59ms/step Actualized series of data [1 2 0 2 0 0 1 0 1 0 1 0 1] results in state: to (take out of) warehouse	This message indicates that the piece is stored
Neue Message mit Topic: f/s/state/hbw 1/1 [==============================] - 0s 33ms/step aktualisierte Datenreihe [0 1 0 1 0 0 1 0 1 0 1 0 1] ergibt den Zustand: Ruhend New Message with topic: f/s/state/hbw 1/1 [==============================] - 0s 33ms/step Actualized series of data [0 1 0 1 0 0 1 0 1 0 1 0 1] results in state: Neutral	After the process has finished, the neutral message is shown again

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REFERENCES

Itrich, A. & Klein, *M.. Lernfabrik 4.0 - Steuerung, Monitoring und NN-Modell (fischertechnik).* Albstadt-Sigmaringen. 2022