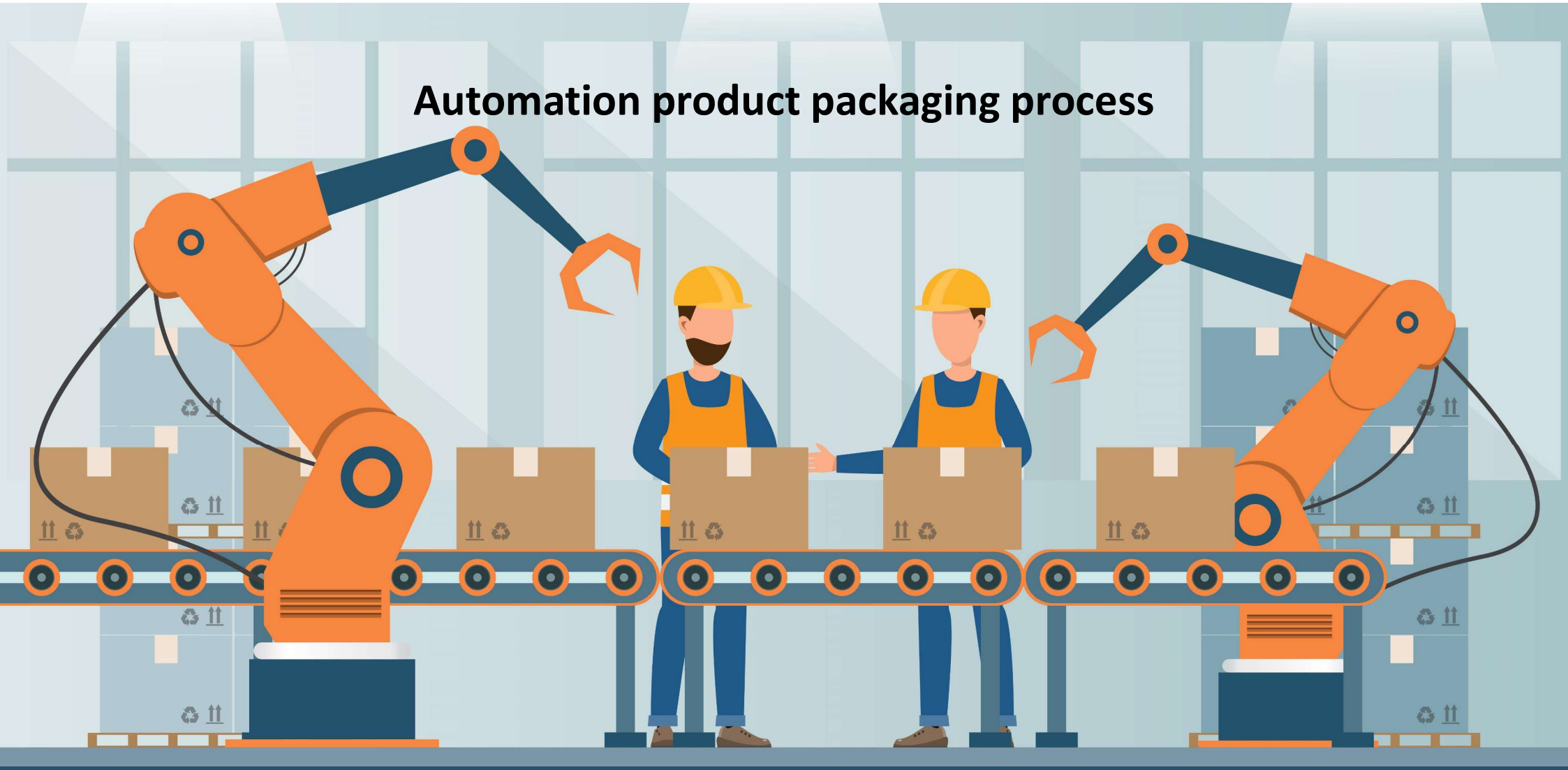
Automation product packaging process



Industrial Automation and Robotics
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Antonino Maio
Ilenia Ficili

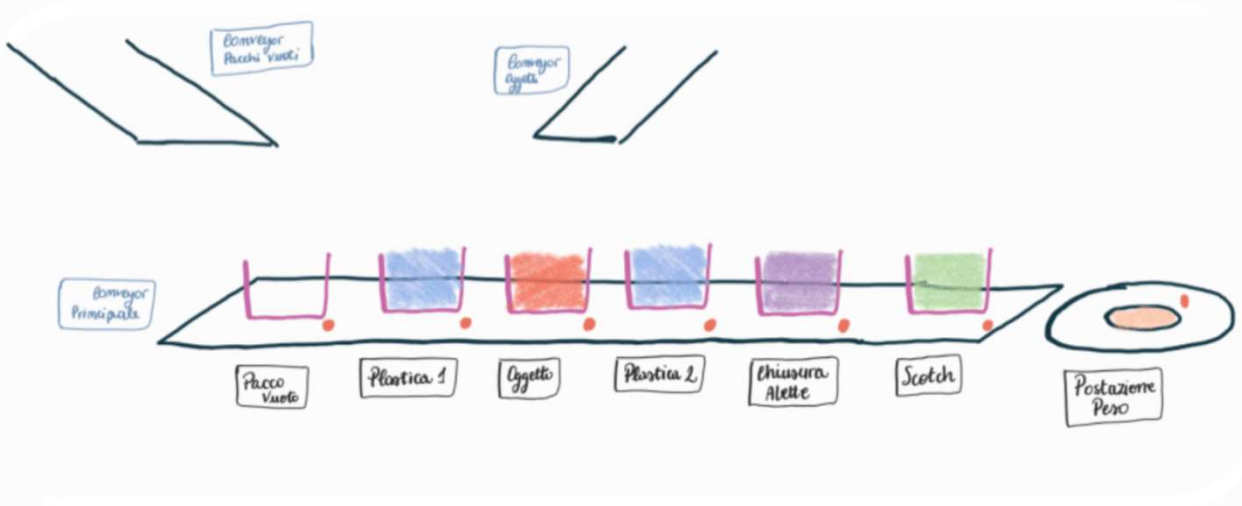
OVERVIEW OF THE HYPOTHETICAL SCENARIO

- The idea behind the project was to automate the packaging process in a shipping warehouse.
- The process start from an empty box, that is delivered on a conveyor belt, and then are defined different working stations to fulfill various tasks:
  - a first layer of bubble wrap is placed
  - the object designed for shipping is placed inside the box
  - a second layer of bubble wrap is added to secure the object
  - The box is closed and sealed;
  - the prepared box is then weighed and delivered to different deposit lockers depending on the weight.

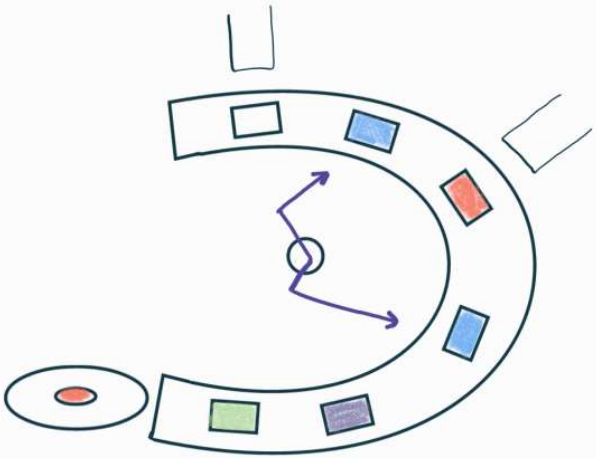
- The shipping warehouse works mainly with heavy packages and for this reason two deposit lockers are dedicated for them, leaving only one for the lighter ones.

Analysis of the possible solution

- In order to achieve an optimal automation of this process we defined the following solution with 5 working station to prepare the box, a station dedicated to the weight of the box and finally a sorting track.
- The first part of the process, which is the packaging, is described as follows:
- All the empty boxes are brought from a conveyor belt to the main working track, which has 5 working stations.
- The first one and third one are used to place the bubble wrap with the help of an automated arm.
- The second stations is dedicated to put into the box the object that needs to be shipped, this is done using a secondary conveyor belt which has on it the object.
- In the fourth station an operator close the box while in the fifth one another automated arm is used to tape the closed box.



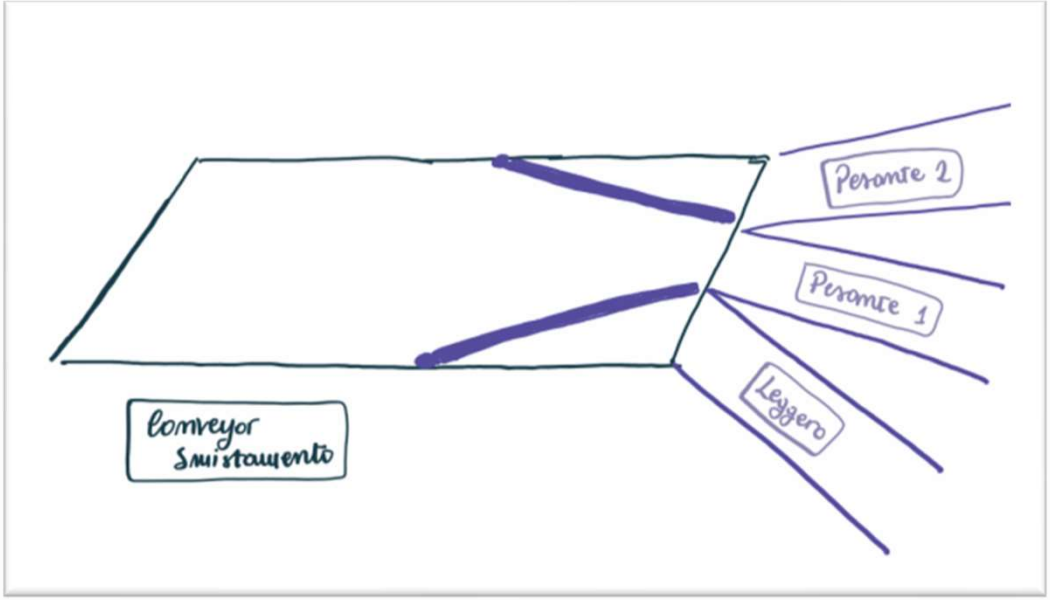
Analysis of the possible solution



- Each working station is provided with a proximity sensor, to detect the presence of a box and stop the conveyor belt for 30 seconds to allow the task to be done.
- Simultaneously, once the working conveyor belt is stopped, the one with the empty boxes is allowed to proceed.
- In order to be able to use the same automated arm for both the first and third station the conveyor belt is designed to be horseshoe-shaped.
- The proximity sensor used is the XS1M12KP340, from Schneider Electric.

Analysis of the possible solution

- The second part of the process is dedicated to the weigh of the package, that are then sorted based on it.
- The weight station is composed of a weight plate with a sensor under it.
- After 5 seconds, that is the time scheduled for the weigh phase, the plate will be inclined with the help of a motor, leading the package to another conveyor belt dedicated to the sorting.
- Here the package will be directed to the specific deposit locker using two rails, each controlled by a motor.

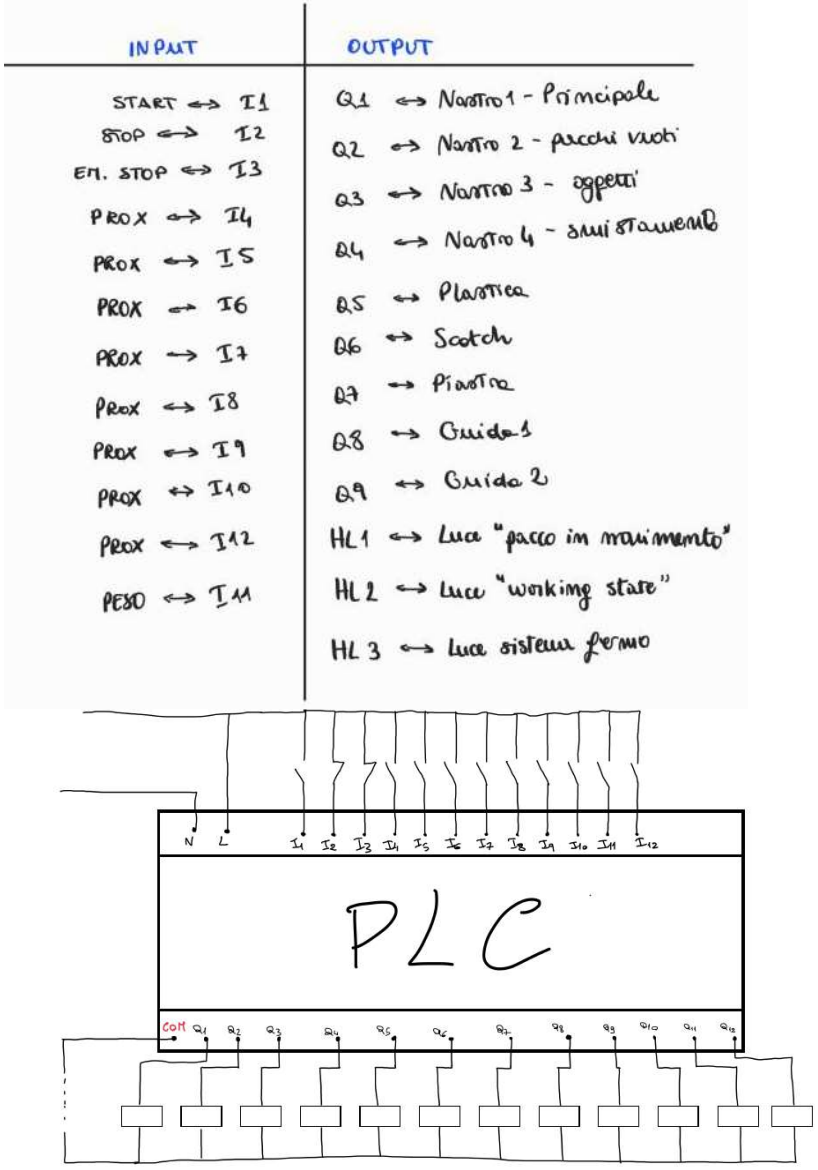


- The deposit lockers are placed at the end of this last conveyor belt, in particular the central one is the 'main' locker for the heavy packages, once this is full, the left one is used.
- Leaving only the right one to the lighter packages.

- The sensor weight used is the Weight Transm. ACT350 Analog PBDP.

PLC Hardware Set-Up

- The PLC hardware set-up is defined in order to have all the 7 proximity sensors connected to the inputs of the PLC starting from I_4 and ending at I_{10}.
- The input I_{11} is connected to the weight sensor which will act as a closed switch if the package is heavier than a threshold, moving the rail to conduct the package to the right deposit locker.
- The inputs from I_1 to I_3 are designed to the Start, Stop and Emergency buttons. The start button is configured as an open switch, while the stop and emergency buttons are configured as closed switch in the software, so in the hardware side they are considered as open switch.



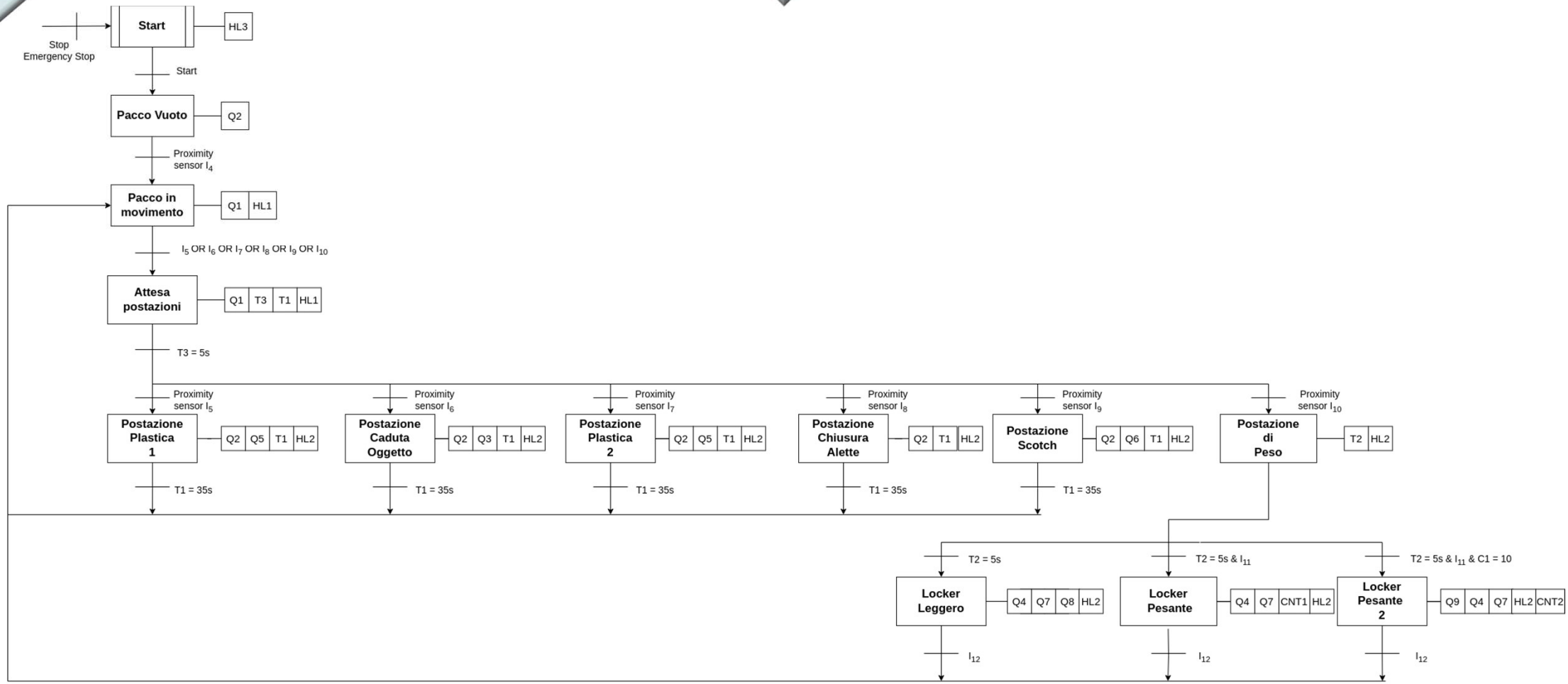
SFC scheme

Sequential Function charts.

SFCs are not text-based programming languages, but rather visual programming languages, similar to the flow charts for computer science algorithms; they are commonly used and easier to represent in scenarios where there are multiple states of operations.

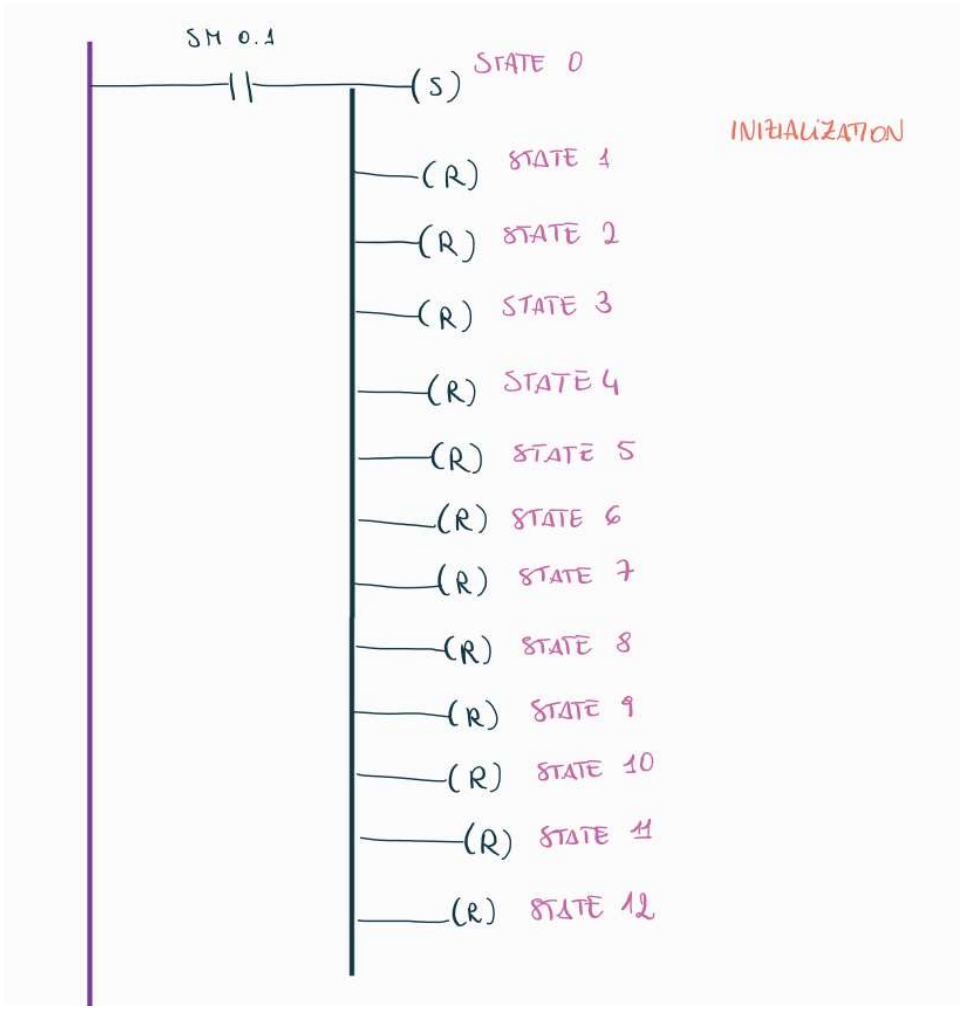
SFC programming language makes it easier to visualize and design complex sequential systems.
The operations are described as separate steps that are sequentially connected, and in particular states or steps are represented by rectangular boxes. A vertical straight line connects the different steps with a transition condition, and each step has a corresponding output.
Outputs are represented as rectangular boxes linked horizontally to their respective state.
Every SFC can also be represented by its equivalent ladder logic.

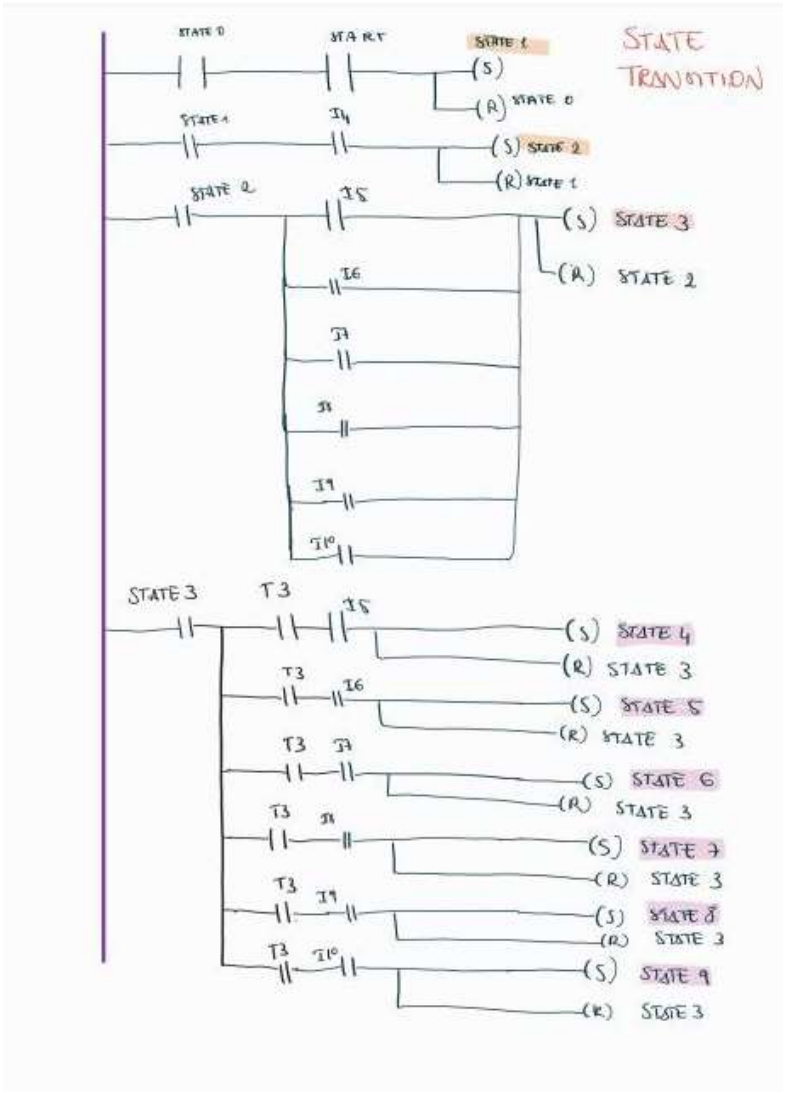
SFC scheme

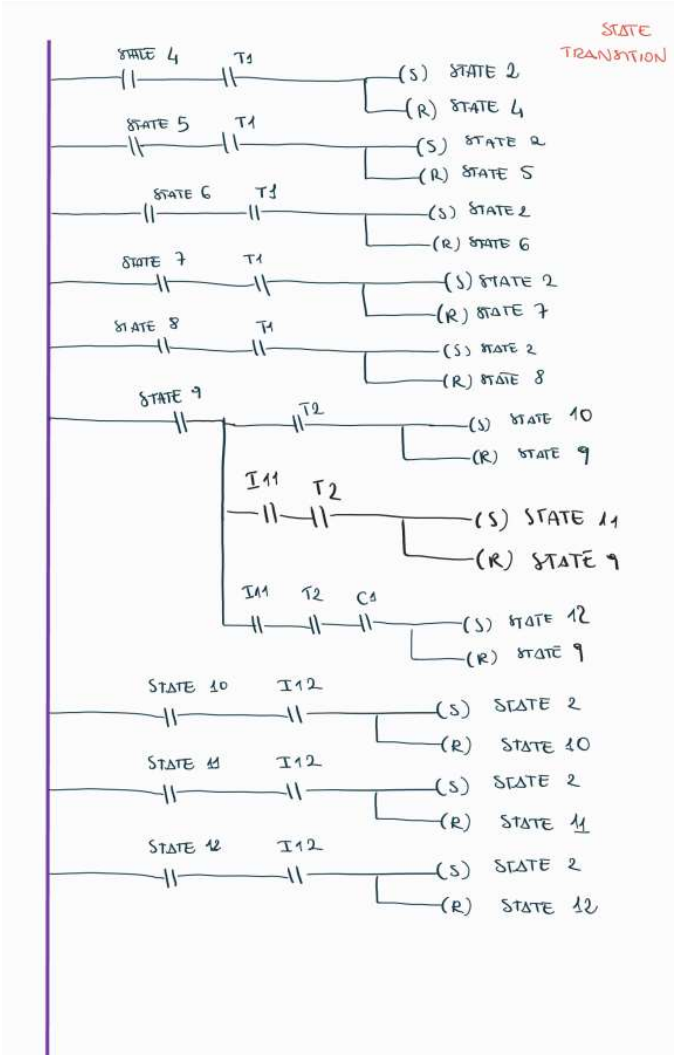

Stop
Emergency Stop
Start
HL3
Start
Pacco Vuoto
Q2
Proximity sensor I_4
Pacco in movimento
Q1
HL1
I_5 OR I_6 OR I_7 OR I_8 OR I_9 OR I_{10}
Attesa postazioni
Q1
T3
T1
HL1
T3 = 5s
Proximity sensor I_5
Postazione Plastica 1
Q2
Q5
T1
HL2
T1 = 35s
Proximity sensor I_6
Postazione Caduta Oggetto
Q2
Q3
T1
HL2
T1 = 35s
Proximity sensor I_7
Postazione Plastica 2
Q2
Q5
T1
HL2
T1 = 35s
Proximity sensor I_8
Postazione Chiusura Alette
Q2
T1
HL2
T1 = 35s
Proximity sensor I_9
Postazione Scotch
Q2
Q6
T1
HL2
T1 = 35s
Proximity sensor I_{10}
Postazione di Peso
T2
HL2
T2 = 5s
Locker Leggero
Q4
Q7
Q8
HL2
I_{12}
T2 = 5s & I_{11}
Locker Pesante
Q4
Q7
CNT1
HL2
I_{12}
T2 = 5s & I_{11} & C1 = 10
Locker Pesante 2
Q9
Q4
Q7
HL2
CNT2
I_{12}

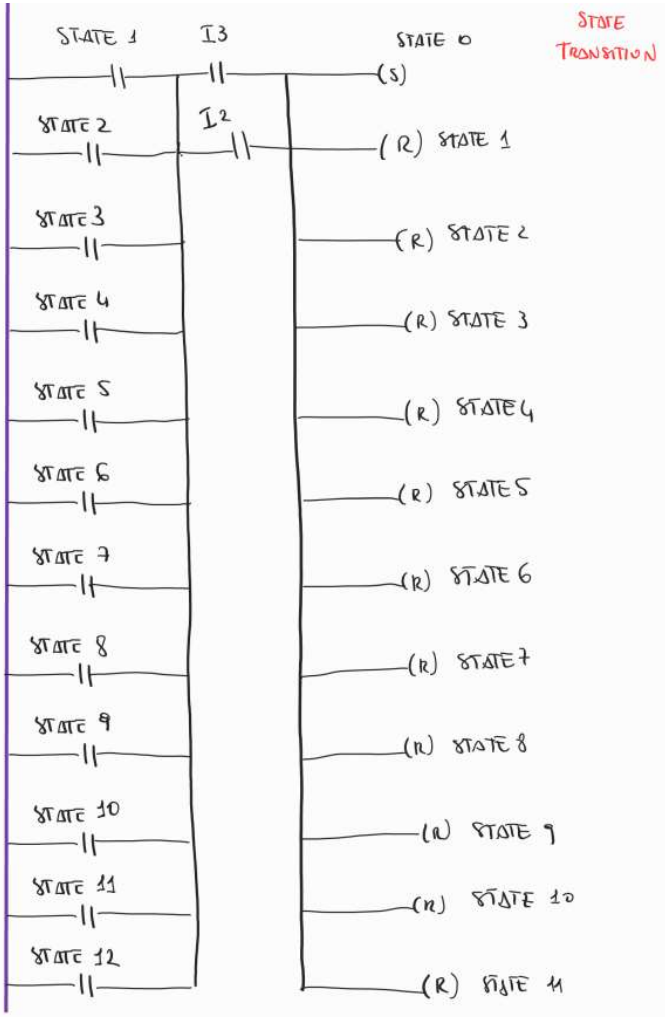
Ladder diagram

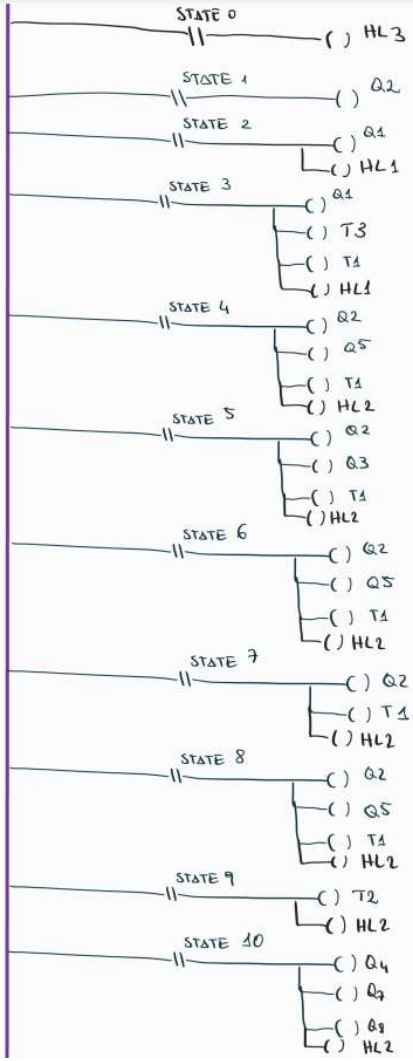
Ladder diagrams are advanced schematics widely used to record logic structures for industrial controls. They are called like this because they mimic a ladder, with two vertical rails (supply power) and as many "rungs" (horizontal lines) as there are to represent control circuits.
The left line is the power line, while the one on the right is the neutral one.
It has developed into a programming language, describing a system through a graphical diagram based on the relay logic hardware circuit diagrams.
Ladder logic is used to build a programmable logic controller (PLC) software and is used in industrial control applications.

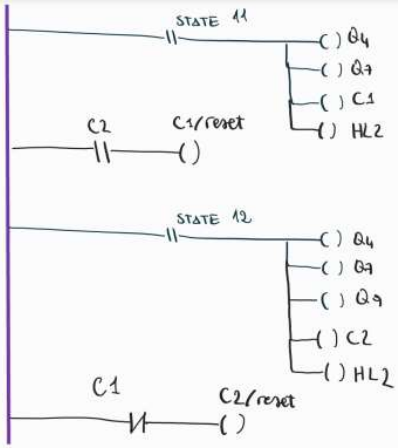

SM 0.1
(S) STATE 0
INITIALIZATION
(R) STATE 1
(R) STATE 2
(R) STATE 3
(R) STATE 4
(R) STATE 5
(R) STATE 6
(R) STATE 7
(R) STATE 8
(R) STATE 9
(R) STATE 10
(R) STATE 11
(R) STATE 12


STATE 0
START
STATE 1
(S)
(R) STATE 0
STATE 1
I4
(S) STATE 2
(R) STATE 1
STATE 2
I5
(S) STATE 3
(R) STATE 2
I6
I7
I8
I9
I10
STATE 3
T3
I5
(S) STATE 4
(R) STATE 3
T3
I6
(S) STATE 5
(R) STATE 3
T3
I7
(S) STATE 6
(R) STATE 3
T3
I8
(S) STATE 7
(R) STATE 3
T3
I9
(S) STATE 8
(R) STATE 3
T3
I10
(S) STATE 9
(R) STATE 3
STATE TRANSITION


STATE 4
T1
(S) STATE 2
(R) STATE 4
STATE 5
T1
(S) STATE 2
(R) STATE 5
STATE 6
T1
(S) STATE 2
(R) STATE 6
STATE 7
T1
(S) STATE 2
(R) STATE 7
STATE 8
T1
(S) STATE 2
(R) STATE 8
STATE 9
T2
(S) STATE 10
(R) STATE 9
I11
T2
(S) STATE 11
(R) STATE 9
I11
T2
C1
(S) STATE 12
(R) STATE 9
STATE 10
I12
(S) STATE 2
(R) STATE 10
STATE 11
I12
(S) STATE 2
(R) STATE 11
STATE 12
I12
(S) STATE 2
(R) STATE 12
STATE TRANSITION


STATE 1
I3
STATE 0
(S)
STATE 2
I2
(R) STATE 1
STATE 3
(R) STATE 2
STATE 4
(R) STATE 3
STATE 5
(R) STATE 4
STATE 6
(R) STATE 5
STATE 7
(R) STATE 6
STATE 8
(R) STATE 7
STATE 9
(R) STATE 8
STATE 10
(R) STATE 9
STATE 11
(R) STATE 10
STATE 12
(R) STATE 11
STATE TRANSITION


COMMAND
STATE 0
HL3
STATE 1
Q2
STATE 2
Q1
HL1
STATE 3
Q1
T3
T1
HL1
STATE 4
Q2
Q5
T1
HL2
STATE 5
Q2
Q3
T1
HL2
STATE 6
Q2
Q5
T1
HL2
STATE 7
Q2
T1
HL2
STATE 8
Q2
Q5
T1
HL2
STATE 9
T2
HL2
STATE 10
Q4
Q7
Q8
HL2


STATE 11
Q4
Q7
C1
HL2
C2
C1/reset
STATE 12
Q4
Q7
Q9
C2
HL2
C1
C2/reset

Bibliography:

- Proximity sensor XS1M12KP340 datasheet https://docs.rs-online.com/f99d/A700000007551054.pdf
- Weight sensor, ACT350 Analog PBDP datasheet https://www.mt.com/dam/product_organizations/industry/Load_Cells/Downloads/Transmitter/ACT350/act350precision/datasheets/01042020_30418575_A_MAR_DS_ACT350_Precision_IT.pdf