Assembling the CIF-01 and CIF-11 with a robotic arm

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28/09/2016

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Document Version: 0.1

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Content

Summary

The goal of this internship is to prove that it is possible to assemble the CIF-01 and CIF-11 with a robotic arm. This internship is part of the TKI project and the case is delivered by Omron who build the products mentioned above. This would be done in accordance with a smart industry way of thinking that would give this single process cell its place within a smart industry based factory. To apply the smart industry or industry 4.0 thinking method there has been looked into Automation-ml.

With smart industry is meant, is the next wave of modern automatization with the newest hardware, optimization methods, factory planning, new way of thinking, production equipment. In short, a forth industrial revolution. This new concept is necessary because companies within Europe have to change their market strategies. The change is that companies will work more costumer based and give their products more room for personal customization.

During the research into smart industry, there has been looked at what smart industry means and how it is already applicable in the automation industry. There has been look at the software package Automation-ML and the standards that it uses. Furthermore, there has been looked at the application frame that Automation-ML uses and if this frame could be used in a smart industry format. The conclusion of this research was that aspects like modularization, distributed control and flexible and reconfigurable manufacturing system could already be implemented.

Automation ml has been researched and there has been specifically looked into the structure it uses and if this could be used effectively with smart industry. There was also looked at the data format it uses and if it could be ported to other environments for detailed development of systems. it could be a good format for a smart industry way of implementing solutions in factory's and even beyond factory level. For now, it is still not enough developed to be of any use to hardware level and software level because you cannot port your solution to a PLC environment. You can however already define your tools and products and how there has to be interfaced between these items.

With the implementation of the smart industry way of thinking there was first looked at the production process form Omron. The first module that was looked at is the most challenging module, which is the entire assembly of the CIF product itself. This module is the most critical module because the entire automation process relies a complete product to undergo the next steps. This module was also the most challenging because it requires a lot of tight maneuvering to get the PCB in its place. This assembly was a success with the robot that is available in the mechatronics lab. This is the UR5 and is attached to a specially designed modular table were simple modules could be attached on.

For every process that was not completed with the setup that was available, recommendations have been added to this report.

1. Approach

The automation industry is changing because of the increasing demand of production lines and systems. Therefore, there must be thought about a new format for the industry. Industry 4.0 or Smart industry as they call it will change the way systems and factories interact with each other on all levels in the production hierarchy.

The red line through the internship is therefore industry 4.0, what is possible now with industry 4.0 and what will be possible in the future. What are the aspects that make industry 4.0 a new way of working and how can we gradually work towards it?

These questions will be answered by first formulating them into research questions. There are many concepts and perspectives, but the fields of research will be extracted in the industry 4.0 chapter and discussed. Every research field will be explained and at the end of the chapter will the conclusion be made. This conclusion has a part that answers the research questions and has a part that concludes which aspects of industry 4.0 can be implemented today.

In the industry 4.0 there will also be a small section that in short reports a side track that has been researched in accordance with industry 4.0, namely Automation-ML. Automation-ML was brought up as a software environment where in you could implement industry 4.0. there will be discussed what the ups and downs are of this environment and where is already could be implemented.

The last core chapter is about the case that has been supplied by Omron in accordance with the TKI project. In this chapter, there will be discussed what the case is and how the Industry 4.0 way of thinking has been applied to this case. The process to realize this case starts with the case itself and how the production process looks like. To give the process form, there has been looked at how the process is divided into modules. The automation step that are necessary will therefore be presented per module at the end of the chapter.

2. Industry 4.0.

2.1. Introduction.

Industry 4.0 or smart industry as we call it is said to be the new way of thinking that is making its way to the production market in terms of how we look at production processes and factory management. The first concept was introduced in 2011 as a means of countering the impending economic problems that would hit Germany and the Netherlands. These problems occur when other countries would be making big steps in terms of product quality and precision production capacity. Many concepts and ideas have been written down over the last few years but there has not been a lot of clear and application proof descriptions of what industry 4.0 has to be. That's why this research paper is written. To find that spot on the horizon, that general direction that this concept has to become.

Furthermore, the other three industrial revolutions were all triggered by technical innovations and because there has been a vast increase of processing capacity together with smart and cheap sensor technology, it is time to put the fourth industrial revolution in motion. Therefore, these questions are asked and answered in this document.

Main question

What is industry 4.0?

Sub questions

- What is industry 4.0 going to change in the production process?
- What is industry 4.0 going to change on process cell level?
- What part of industry 4.0 is and can already be implemented within the industrial automatization of today?
- What part of industry 4.0 will be implemented in the near future of industrial automatization?

2.2. Pillars of industry 4.0

Smart Industry is built on three pillars:

• High quality, network-centric communication between players, humans and systems, in the entire value network, including the end-users;

• Digitisation of information and communication among all value chain partners and in the production process on all levels.

• Granular, flexible, and intelligent manufacturing technologies, adjustable on the fly to meet highly specific end-user demands.

These three pillars can be related to multiple areas of interest and research.

The figure below illustrates the overlapping subjects between three main subjects of industry 4.0. These subjects can be linked to the pillars of industry 4.0 that have been described above.

the first pillar can be found within all primary subjects of the figure. This is because it contains elements like for instance product quality. Quality assurance and improvement can be done by collecting data (digitization), improve your bond with your customers (network centric) or improving your manufacturing equipment (manufacturing technologies).

The second pillar can be found within the subject of digitization and network centric. These subjects represent the way all data and information will be represented, processed, applied and obtained.

The third pillar can be found within the subject of manufacturing technologies. This subject gives the solutions that are necessary for this pillar to succeed. New ways of thinking, architectures and equipment will be necessary to use this pillar effectively.

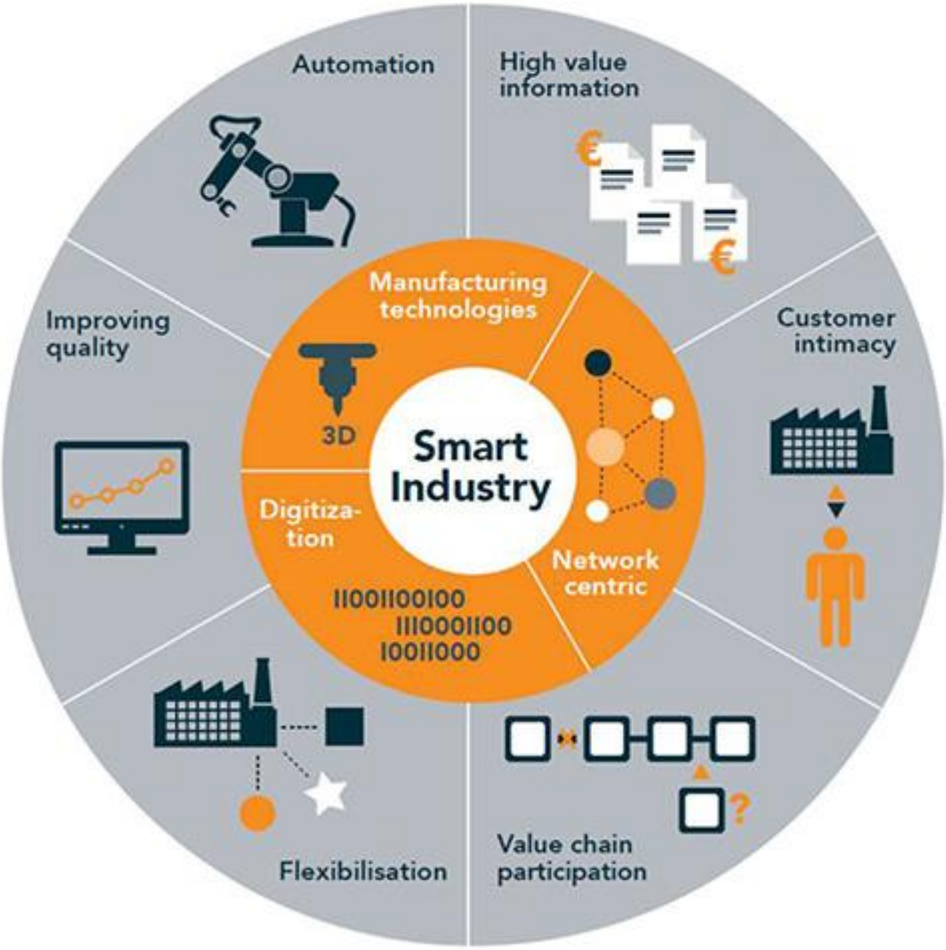

Figure 1: Visualization of Industry 4.0

2.3. Research fields.

The research subjects that are being discussed in this chapter make up the technical challenges that have to be faced, further more will be discussed how far we already are on those subjects. The research fields that are now being discussed are chosen specifically because they can be placed underneath one or multiple pillars of industry 4.0. Every research field will be compared to the case to see if it is applicable.

2.3.1. Modularization.

Modularisation is the dividing of a certain chain of value into clear blocks of actions, resources, inputs and outputs to the outside world. An example of a value chain could be a production line that is then dived within process cells. These process cells have resource inputs like: casings, LED's, PCB's and outputs in the form of sub or full assemblies. Between these inputs and outputs is a process that is bordered within the module. The module could also use other resources like information and energy. All these aspects have to be described in order to fully define a module.

This is necessary because production processes can be easier automated when they are plug and play, flexible and have few interdependencies. Industry 4.0 needs to be able to connect to every other module and needs to be independent of other modules so that they can be decoupled and re-used, reconfigured and be optimised individually. The subject of modularization fits in the pillar of more flexible and intelligent manufacturing technologies. This has to be done on an enterprise hierarchy level so that factories can be used as modules that keep being dived in smaller modules. The hierarchy would be as follows, enterprise, factory, production line, process cell and module. Everything after a process cell would be simply called module because every component should be able to behave like one. There has to be a complete change of process architecture in order to use modularity, every process should be divided into modules that later can be automatized. This would make the jump to automatization smaller because of the limited action within the module and because you can automate your process in parts. Modularization has to happen within digital systems as well as within company hierarchies, structures and among production partners. Along the entire value network. There are obviously already processes that are divided within modules, but these are not yet implemented with a digital layer. This last step is what defines industry 4.0 because the digital layer will provide increased insight and communication capabilities. [1] [3]

This subject is certainly applicable to the case of Omron. The production line is already thoroughly modularized and this will make the change to full automatization easier. The robot can now be programmed in such a way that all problems can be tackled on at a time.

2.3.2. Self-optimization

Machines are going to become increasingly smarter in the future of automation, this development will give new solutions for the automation industry. Self-optimization is a subject that requires a lot of new analytics and software. The machine has to understand the data that has been collected and how to use it effectively. Were a robot used to have a controller of his own that would simply take directions, this is changing into a setup that has one controller for the entire production cell that gives data to the next controller that stands above it in a hierarchy. This higher-level controller would use the data to continuously optimize the production line.

This subject is not going to be covered within the internship and the case. This will be done by other partners that Omron works with. The subject is of course a vital part of industry 4.0 but can later be implemented when the main automation is fully functioning. [2]

2.3.3. Distributed control

The analysing and controlling of for example a robot, has to be expanded to make the system optimize itself. The system will be an on itself standing module that is constantly monitoring and optimizing itself. This means that the controlling is not done from a single controller, but that the central controller is only monitoring and reacting on inputs of the smaller individual production cells. Every process cell will make its own decisions and then communicate these decisions to the global controller, this controller will then make decisions based on what the smaller process cells decided. [1]

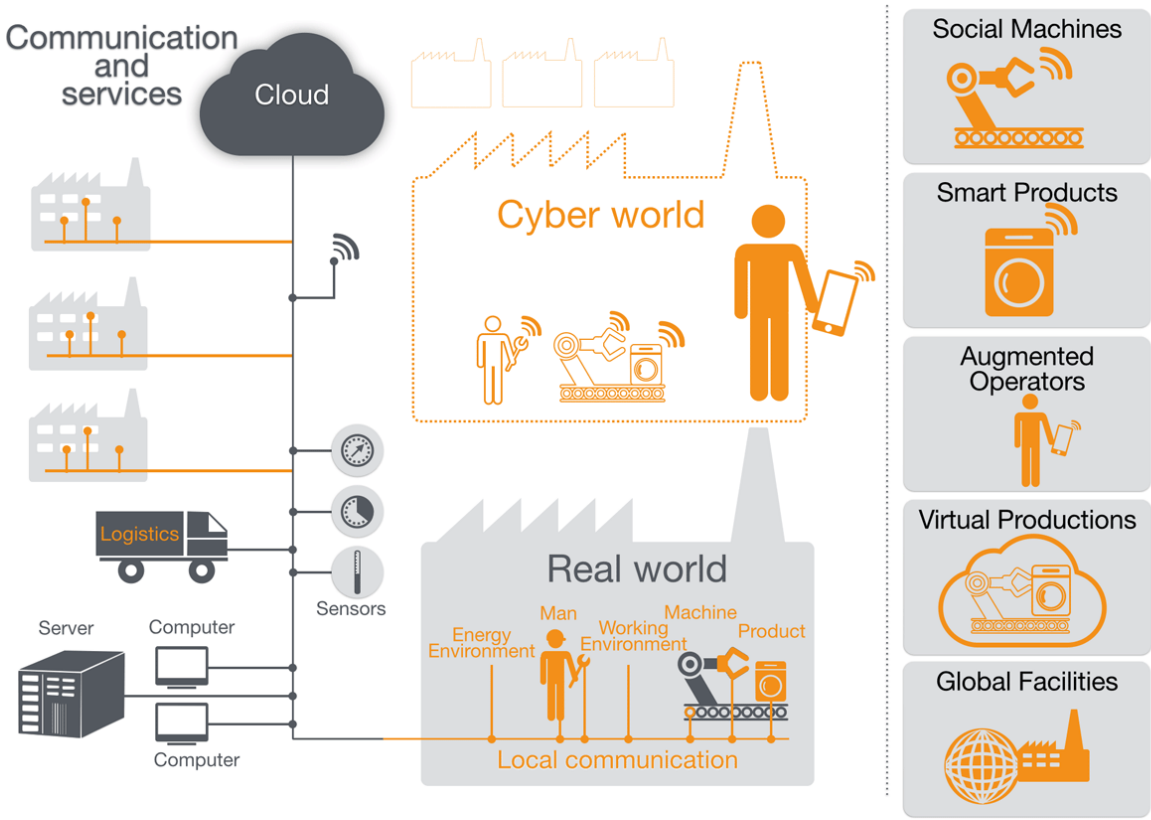

Figure 2: Visualisation of the different aspects in the industry 4.0 format

This step is necessary because the flow of communication would be too great for a central core to handle effectively.

This subject will not be covered in detail. The robot will be a standalone production cell that could be connected to a network on a later stage. Still this is something that will not be covered within this project.

2.3.4. Rapid manufacturing
Time to market has to be decreased in order to respond fast to customer demands and trends. Because of the recent developments in 3D printing together with the ability to outsource big parts of a production chain, the way is paved to bring highly customized products the market fast. These developments fit flawlessly in the industry 4.0 format because of the flexibility that production processes are going to need. When processes are more flexible, producing smaller batches in rapid succession will become more cost effective [1] [2] [4]

Figure 3: Picture of CIF products, who are produced by Omron

Rapid manufacturing fits into this project because of the flexibility that the production line already have and is going to keep. The types of products that have to be produced, have to be produced on demand and in small batches. Therefore, it is used in the production line but not covered in detail within this project.

2.3.5. Reconfigurable and flexible manufacturing systems.
This research subject will benefit a lot of internal and external modularization. With the changes in architecture, It will be far easier to reconfigure your production line and your production process. These changes in architecture could be for example, make all hierarchies into independent blocks that can be reused. You could add functions and production steps based on the product that has to be produced. This would later be used on a production cell level, the cell detects what product it is and what kind of production steps have to be taken to complete the product. For flexible manufacturing systems there is already a solution where you add recipes that that can be simply changed. This recipe setup is already used within the machine building branch for the food industry. This is still machine independent and should become production cell independent. [1] [2] [3]

The Reconfiguration of the production line from Omron is already done quickly because of an order based system. There has to be looked at the possibility to expand this system to the new automated version as well. This would make the process of reconfigurations faster because the system immediately knows what product has to be made and how many. This subject is used in the project but not covered in detail because it is already present in a good format within the production line.

2.3.6. Cloud computing in the industrial environment.
Every production cell will be thoroughly monitored and all that data has to be stored within a cloud server so it can be analysed over longer periods of time. Furthermore, there have to be robust cluster algorithms to store all this data effectively and strong a control system to process it. Literally everything that could have a fail mode could be monitored to minimise downtime and understand how much a tool, machine, or product can take before it breaks. [1] [2] [3] [4]

This subject will not be covered within the project because it is not applicable yet. It could be implemented later when the production process Is fully automated and operational.

2.3.7. Internet of things and services.
Because the world gets more and more connected. Services like remote maintenance and helpdesks can work more frequent and more effective. Because of the constant data collection, cloud systems have to be in place to store all the data. Companies can work more effective and can instantly see what the product problem is at that moment because of constant monitoring. They can see where it went wrong and how it can be fixed. Because of this data collection they can also take measures to produce it more durable. [1] [2] [3] [4]

This subject will not be covered within the project because it is not applicable yet. It could be implemented later when the production process Is fully automated and operational. For the case from Omron it has little value at the moment because the project only has the scope of on a single production cell.

2.3.8. Supply chain flexibility.

Suppliers and manufacturers have to be constantly talking through a supply network and have to be integrated together, this will give maximum flexibility and will give minimum storage time for resources and products. When a product is needed in three days and it takes one day to produce, this means that you can start producing tomorrow if the supply chain is flexible enough. This again minimizes storage time, storage space and energy consumption.

Omron already uses this strategy and this makes their production lines very efficient. They make extensive use of FMEA and time management tables. When the production process has to be full automated it should be robust enough to maximise the uptime. When the uptime cannot be guaranteed, could this have serious consequences for the product and resource stock. Omron does maintain a warehouse where a buffer is stored of every product so there is a certain amount of fault flexibility present. [1] [2] [3]

2.3.9. Collaborative networks.

For most of the research subjects is a very tight collaboration between companies necessary to achieve total value chain insight, control and flexibility. Still it is hard to achieve this collaboration and companies are holding back. Still more and more companies are beginning to see the benefits.

The network architectures are shifting form a clear end to end network to a mesh network which has arbitrary rules to make sure that the data is received. These communication networks should be able to communicate on a higher process hierarchy, for instance, a factory mesh network should be configured in a way so that it is constantly exchanging data and communicating. To extend the control and insight there should also be close cooperation between companies and their suppliers.

This subject is parallel to distributed control systems because these control systems also have to communicate properly to make certain decisions. [3] [4] [5]

This subject will not be covered in detail because the case contains only a single process cell.

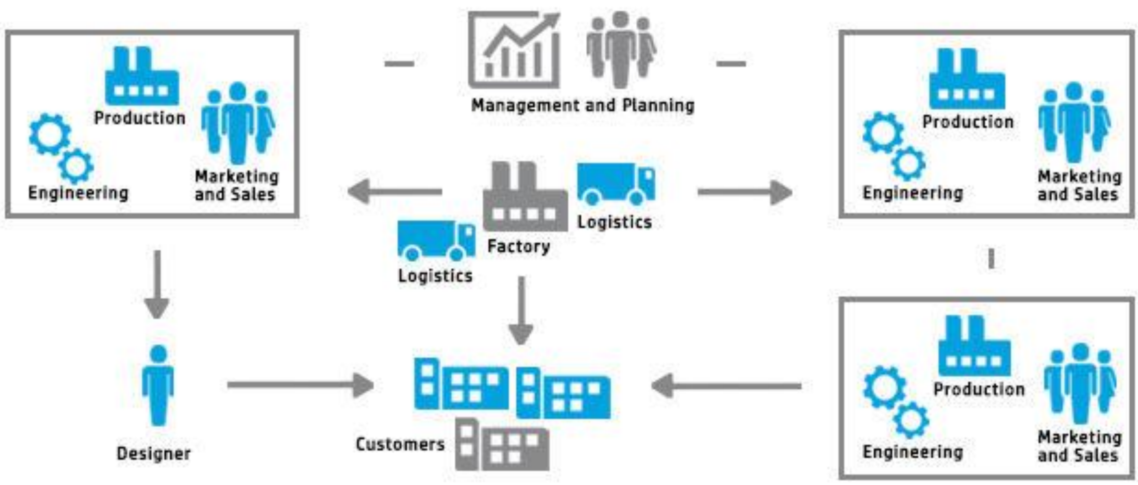

Figure 4: visualization of a process chain in an industry 4.0 format

2.3.10. Distributed manufacturing

Because of the vast insight in the production and supply network, it will be far easier to outsource and produce parts on multiple factory sites. This means that products will be produced all over the world and assembled on yet another location. This can only be done when production chains are calibrated to the maximum with respect to each other. Companies already do this on a grand scale. Still, this can be made far more efficient when there is reliable insight in the supply chain and cooperation over that entire chain.

This is a subject that will not be covered within this project. [1] [3] [4]

2.3.11. Supply chain visibility.

The companies who have the best insight in their entire production chain will benefit most of industry 4.0. This is because that you will have a real-time insight in everything that is happening and together with smart analytics, problems can be spotted before they happened and appropriate action can be taken. [1] The real-time insight will be available because of the cyber physical system setup that is key to industry 4.0.

Supply chain visibility will not be covered in this project because the process cell is only a small link in the complete chain. [3] [4]

2.3.12. Value added services.

With vast data collection because of constant monitoring, there are chances for new kinds of services. This can range from preventive maintenance until help services. There are chances to create more revenue because of the increase of insight in processes and systems.

This subject will not be covered within this project because there will not be any production data monitored by the system that is going to be the result. [3] [4]

2.3.13. Real-time operating systems.

If systems have to respond real-time to production process threats, the processing of all the incoming data has to be done real-time. Everything has to be time related in order to respond in time.   A real time responding system is summed up by the following definition: The maximal time needed to respond to a certain problem, plus the maximal time the systems needs to process the information to give a realistic view of the momentary situation, plus the maximal time to implement the solution for that particular problem. [1]

2.3.14 Individualized traced data.

Every module has will have its own id number, for example, a process cell or even a sensor. every piece of data has to be retraceable to validate the origin. This has to go both ways, form the sensor to the product or tool and back. All this data is necessary to create the best possible insight in the production chain.

This subject will partly used because every module will have its own id number very early in the development process. By means of data, there will be no coverage in the project. [1] [4]

2.3.15. Virtualization of the process chain.

The term cyber physical system is more and more integrated within the automation world. This means that a virtual system clone is made and constantly enriched with real world sensor data to get the best virtual representation of the system. Everything that is then decided for this individual system is then linked back to the real-world system to implement it. A feedback loop is established with real time insight.

In this project there will not be worked with an entire production chain. Because of this reason, there is no use of covering it in the project. [1] [3] [4]

2.3.16. Simultaneous planning of products and production processes.

Because of full production chain management and integration that is necessary to achieve full flexibility and control. You obviously would need to simultaneously plan everything that is critical to the production process. This would minimize downtime and produce for instance if you need a batch three days from now and it takes a day to make a batch. You start making that batch the day before you need it, this minimizes downtime and the storage space that is needed.

This subject will not be covered because the planning is done on a different hierarchy level then were the project is based on. [3] [4]

2.3.17. Simulation and modelling of products and processes.

Every system will have its own modelling, process steps, feedback, feedforward and external communication. This means that there have to be massively simulated to make sure the entire value chain works smoothly. There have to be clever algorithms that can do this continually and correctly. When a certain simulation goes wrong, the consequences could be severe for the production line. So a certain amount of self-awareness in the machine would be necessary.

Simulation will be done over the entire process cell because all the kinematics and time related topics have to thoroughly work together to make sure everything works in the end. [1] [4]

2.4 Answering questions

2.4.1. What is industry 4.0 going to change in the production process?

Production processes will be far more flexible and monitored constantly to maximize uptime.

All the data will be stored and used to optimize the production process and give real-time insight in the present production steps. The process will be able to be reconfigured depending on the product that the line has to produce. The production process will be modularized to make the step to full automation easier. The production line itself will become a module of a greater system that interconnects multiple companies and factories to make one linked value chain. This value chain can then be traced in real-time in a virtual environment. See figure 4 for a visualization

2.4.2. What is industry 4.0 going to change on process cell level?

Production cells are going to be far more independent than they are now. These cells are going to monitor critical information themselves and take decisions according to that information. These decisions will be centered around self-optimization, self-maintenance, self-calibration and self-configuration. In short, every production cell will make its own decisions. Also cell to cell communication will be important so that the next cell in a chain knows when to power up and what to do with the product that is transferred into the cell. All the cells will be plug and play and would be able to communicate with minimal configuration.

2.4.3. What part of industry 4.0 is and can already be implemented within the industrial automatization of today?

When certain technologies are not really present yet like most bigdata solutions or self optimizing algoritms, other steps can already be taken and have been taken to make the transition to an industry 4.0 architecture. When the process steps are modularized, would it be far easier to automate the process in steps. This approach would reduce the capital strain on a company.

Next to modularization you also see an increase in company cooperation on basis of knowledge exchange and production distribution to tackle challenges that are present now and in the future.

2.4.4. What part of industry 4.0 will be implemented in the near future of industrial automatization?

Steps are taken to make algorithms that analyse the data to make it useful to companies. These companies will rapidly start to automate the simplest parts of their production systems and monitor these production cells to get their proof of concept. These process cells will become increasingly complex until everything is automated. The complexity will be found in the increasingly smarter hardware whereby the exchange of information becomes more and more central.

2.5. Automation-ML.

Automation-ML is a software environment that uses a hierarchical structure to describe software elements, hardware elements, system elements and their interfaces. It has been brought up as the one application for implementing industry 4.0. These elements can be further defined with the help of actual 3D models that can be linked to these descriptions. All these aspects make of a very complete virtual representation of a system element. The strength of Automation-ML compared to other environments of the same type is that it uses only open standards that are widely accepted in the industry, like PLCopenXML. This means that when it is fully developed, it would be possible to port your described data into almost every other system development environment. An example would be, a PLC environment to program the hardware that is going to be used for the machine that is being build.

The description part of Automation-ML uses an abstract, top-level description of every system element and that’s why there are only limited option when it comes to describing detail in the environment.

There has been looked into the potential of Automation-ML and what it can already be used for. The conclusion here is that although most elements can be described, it is not developed enough to use effectively. This is because of the problem it still has with completely porting the described information to for example, PLCopenXML. This means that you cannot enter the next stage of development with the data that has just been generated in Automation-ML, rendering it useless.

When Automation-ML has matured, it could be a good descriptor for systems. In the internship, there has been tested with a relatively simple system in terms of number of elements. The setup that has been used to implement the next stage of the internship was only one process cell. It could be a good test if Automation-ML is tested with a far greater number of elements so that it can prove it is suited for every level in a production chain.

3. Case from Omron.

3.1. Introduction.

Omron has a production line that they would like to have automated. To help with this challenge, there is looked at the functionalities that Smart industry could give. The main part of Smart industry that is going to be used is the physical layout and architecture format. What is meant with the physical layout and architecture format is the modular approach to systems and hardware, the fast reconfigurability and the plug and play approach to new modules.

The production line produces four products that are related to PLC computers. These products are PLC interface modules called CIF that must be assembled, tested, labelled and packaged within the production line. The CIF are made in such a way that they can be connected directly on an interface

Figure 5: The CIF-01 and the CIF-11 respectively.

port within the PLC. Through the CIF, the PLC can be directly connected to a PC to program or to monitor the PLC. The production line can produce 4 types of CIF interfaces, but there will only be two products that will used as exemples for this use case. These products are the CIF-01 and the CIF-11. The main difference between these products is that they both have a different PCB and therefore have a different kind of connector. This means that the assembly and testing processes are different. These differences will be discussed per chapter is any deviatio in the production process takes place. The process charts of the production process and the biggest modules can be found in appendix A

3.2. Buffer location

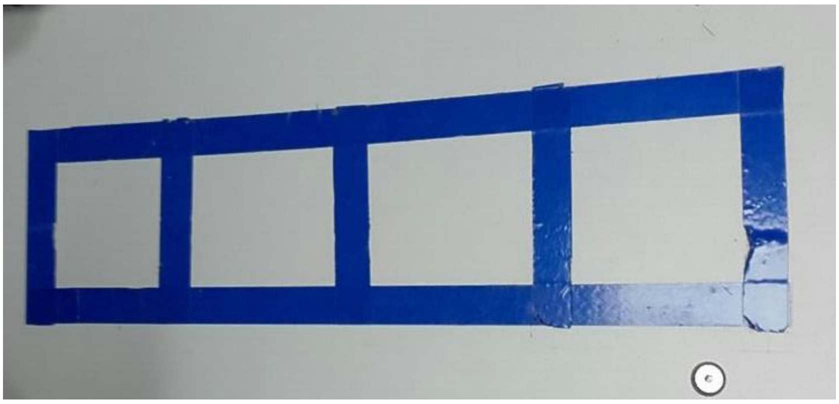

Figure 6: Picture of a buffer location within the production line.

Throughout the production line there is made use of buffer locations. These are small patches on the production line tables that give the operator a clear begin and end of each production module. With these locations, it is also almost impossible to misplace products or to lose them. This is because these locations are chosen in such a way that they are close to the current module, but that they do not obstruct the workflow of the operator.

3.3. For full automation of the production line: buffer locations.

The buffer location is going to be maintained within the full automation line design. This makes it very clear when a certain production module starts and stops. Also, the Tape or lining that is used can be used to distinguished certain locations. The buffer locations are marked in blue in the figure below.

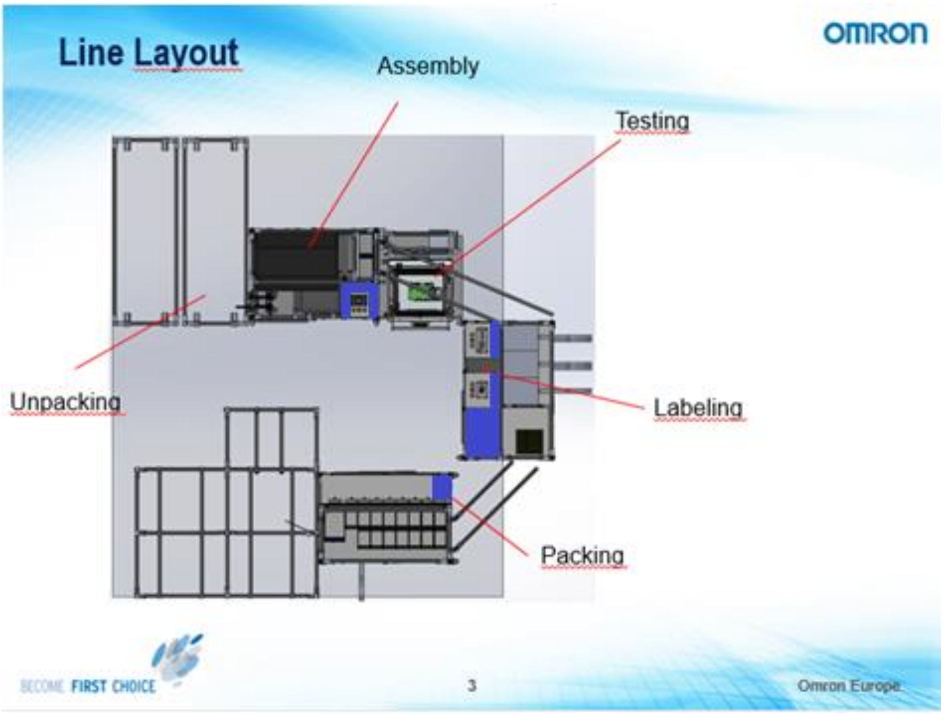

Figure 7: production line layout.

3.4. Unpacking.

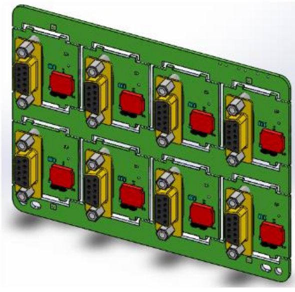

Figure 8: PCB breakout rack

This module would be an option to the line and will be covered when there is time left within the internship. In this module, the PCB's must be broken out of the PCB breakout rack and placed on a buffer location with the right orientation. There are eight PCB's in every breakout rack so the breakout rack is slotted into a frame, the rack is wedged until it gives in, the rack is then lifted and turned 180 degrees to let the first waste piece fall, the first four PCB's are broken out and placed on the buffer location, the rack is wedged again, the rack is again lifted and turned 180 degrees to the second waste piece fall, the last four PCB's are broken out and placed on the buffer location and the third waste piece falls in the waste bin.

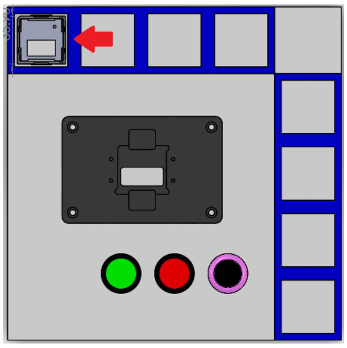

Figure 9: assembly module with casing in the right orientation

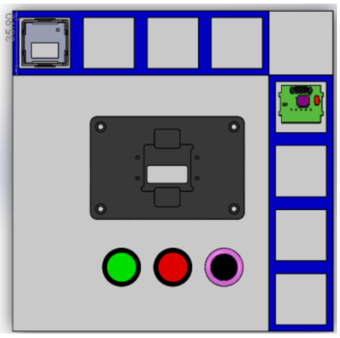

Figure 10: assembly module with PCB and casing in the right orientation

After this process, a casing must be taken and placed in a buffer location with the right orientation.

This casing must be picked out of a production line input bin. After this process the next module will begin.

Figure 11: Production input bin with casings

3.5. For full automation of the production line: unpacking

If this process must be fully automated it should be able to detect, grab and effectively break out the PCB and the casing. The process must be accurate enough to turn the break out rack and put it back in the frame. It should also be able to pick a casing out of a production line input bin.

3.6. The Assembly.

Figure 12: Picture of a Ledguide.

In this module, the previously place components will be used with the addition of a LED Guide. The casing will be placed within a jig. After the placing of the casing, a led guide must be taken from a in. This bin is placed on a location with a light gate that will go off when a hand has passed underneath it. When this is not done, an alarm will go off.

When the led guide is taken, it is placed in the top right corner of the casing. The led guide has a small eminence that fits within the slot that is located within the top right corner. After the ledguide has been be inserted into the casing, the PCB must be put in place. Here the process deviates per product.

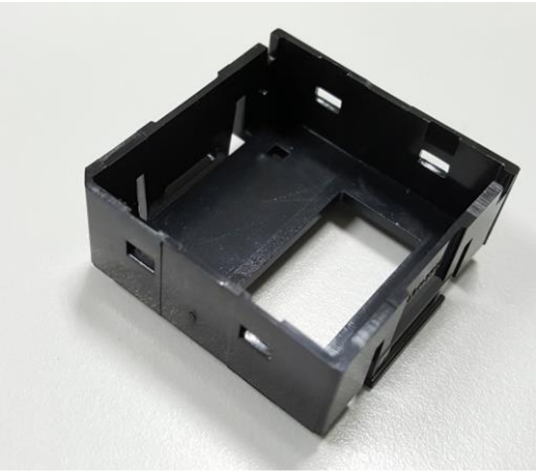

Figure 13: Picture of a CIF product casing.

Figure 14: Picture of a CIF product casing with a Ledguide in the slot.

3.7. CIF-01 PCB assembly.

The CIF-01 has a big VGA port on the top side of the PCB (note that the product is assembled upside down) that interferes with this assembly step. Therefore, the PCB must be put lightly on the casing and make sure that one side of the PCB has its teeth in the small gaps that are directly above the mounting holes of the casing. When this position is verified, there can be applied an angular force towards the side where the teeth are in the gaps. When the correct angle and force are applied, the PCB will slide into the mounting holes.

Figure 15: Indication of one side of the mounting gaps within a CIF casing

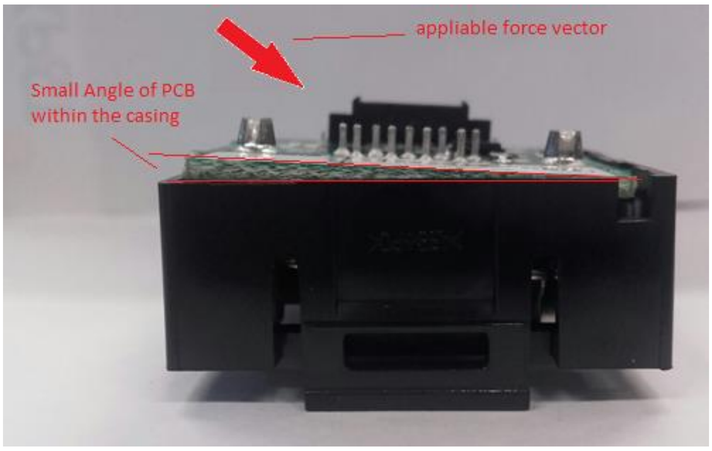

Figure 16: Instruction picture of PCB assembly of a CIF-01

3.8. CIF-11 PCB assembly.

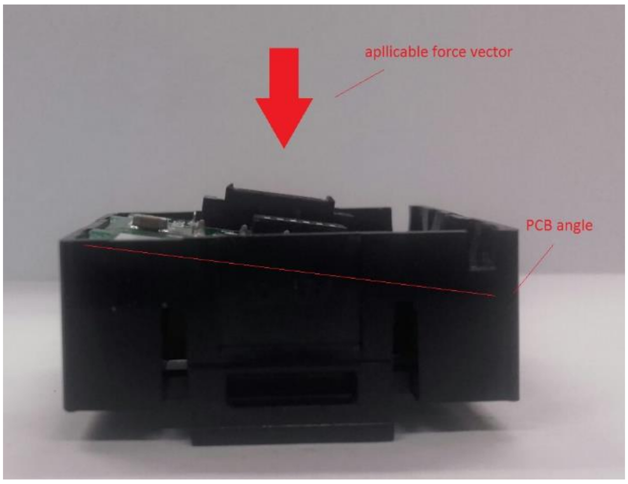

Figure 17: Instruction picture of PCB assembly of a CIF-11

This product is simpler to be put together because it has no obstructing components on the upside of the PCB (note that the product is assembled upside down). With this product, the PCB can already be placed in the mounting holes on one side and the force can be applied vertical downwards.

This jig has a sensor that detects the casing and will detect a PCB when it is placed inside the casing. These sensors will also give a signal if there is no PCB detected inside the casing so there is a failsafe already in place. When either product is assembled, it will be placed on a buffer location to proceed to the next module.

3.9. For full automatization of the production line: the assembly.

The automated process should be able to detect, place and assemble the products accurately. There is a big difference in material properties between the components that have to be assembled. this should be taken in account if something is going to be used like a vision system. There should also be checking measures in place so that it is possible to verify the steps. There also have to be automated systems in place so that every component can be picked up with the right orientation. For the complete assembly, there should be something in place that measures the applied force to make sure that the product will not be broken.

3.10. Testing.

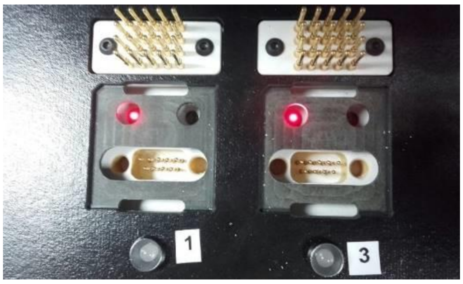

Figure 18: CIF-01 test sockets

The assembled products must be tested within a special testing machine called a checker. In this machine a maximum of four products can be placed. All four products must be placed within slots so the lid can be closed. The lid must be closed with a certain amount of force. When there is more force necessary, would this mean that one of the products has not fallen correctly into a slot and must be inserted again. When all products are correctly placed and the lid is shut, a program is run through the products to test them. The checker displays the information when a certain product does not pass the test so it can be taken out. Every product that does not pass the first time into the checker gets a recheck within a different slot together with more recently assembled products (this depend on how many failed the first test). If a product fails the second time in the checker, it will be put in a special pink bag with a recite that explains the error so it can be fixed manually.

3.11. Product process deviation: Testing of the CIF-01.

The CIF-01 is tested by simply putting products within the slots and running the program. The checker will review the placed products and show on the screen which ones passed and which ones didn’t pass. According to this outcome, appropriate action can be taken by the operator.

3.12. Testing of the CIF-11.

The CIF-11 must be tested in multiple ways because there are multiple settings available. The products must be placed within their specific slots and a program must run. When the program is running, the checker will request operator input in the form of changing the switch combinations on the dipswitches that are placed on the products. The test sequence can be found in appendix B

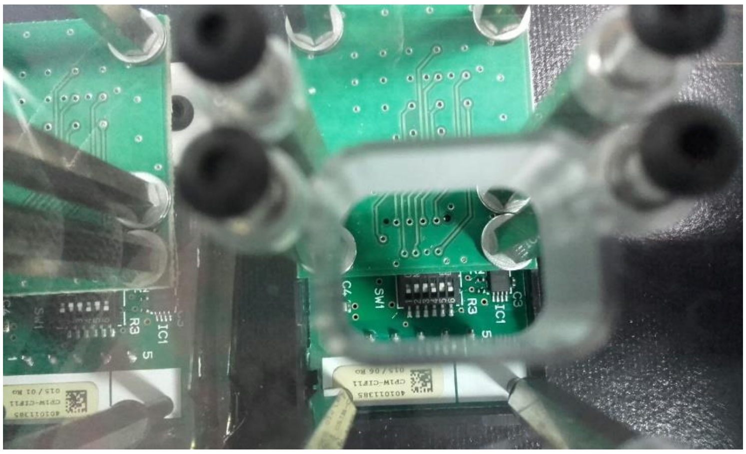

Figure 19: Top view of the testing of the CIF-11

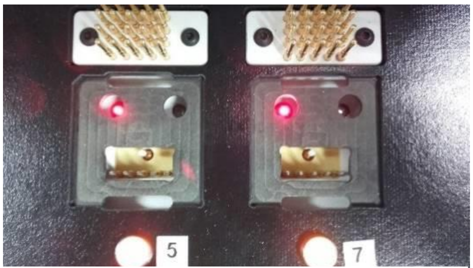

Figure 20: CIF-11 test sockets

If the four CIF-11 have passed this procedure they will be placed on a buffer location to proceed to the next module. Every product that does pass gets placed on a buffer location to proceed to the next module.

3.13. For full automatization of the production line: testing.

The inputs and outputs of the checker should be linked to the overall line control system so the automated line can respond to the information that the checker provides. Again, the system should be accurate enough to handle the products with the desired orientation so fall correctly in the desired slots.

3.14. Labelling.

The products that have passed the testing module will be labelled here. This starts by putting a product in a jig that is made to hold the products on their side. When the product is placed, the printer will give automatically the right label if all machine settings are correct. The first label can be applied and the product can be placed within the second jig. When the product is in the second jig, the next label can be applied.

Figure 21: The production line label printers

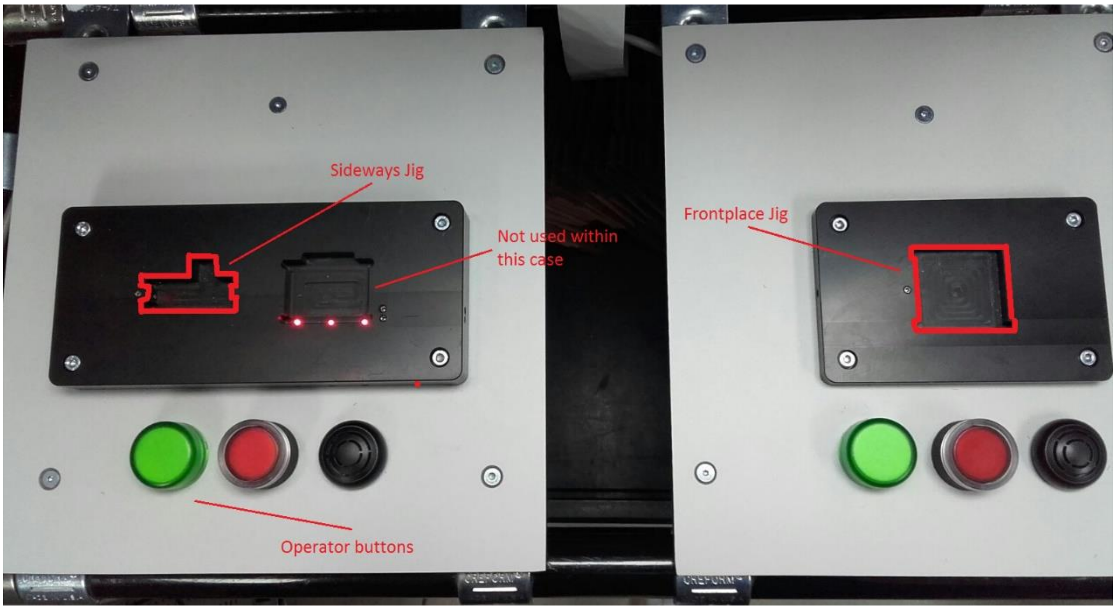

Figure 22: Labelling jigs

After that, the products that have passed the checker and that have been correctly labelled will be placed on a buffer location to proceed to the next module.

3.15. For full automation of the production line: labelling.

Labels and adhesive tapes tend to be hard to extract and apply. There should be found a way to extract the label with the right orientation and place it straight without air pockets. Also, the product itself has to be placed within the jig with the right orientation.

3.16. Packing.

The products that have been labelled will now be packed in blue bag that is sealed with a small piece of adhesive tape. The bag is then folded once and placed in a box. This box has to be folded out of an

Figure 28: Flow chart of labelling module

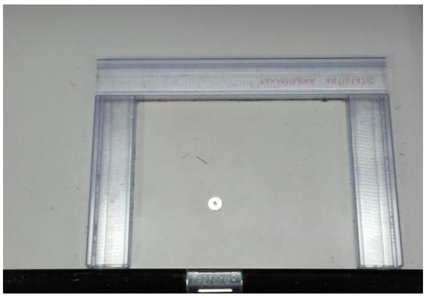

Figure 23: Boxholder for packing

unfolded pre-cut piece of cardboard. The exact steps can be found in appendix A.

The box must be placed in a holder and if it leaves that holder when not all steps have been completed, it will give an error signal. There is a pick to light system in place to make sure that every booklet or component is taken and placed within the product box. This system works by indicator led’s and light gates that go off when passed. When all requirements are met will the system not give any errors.

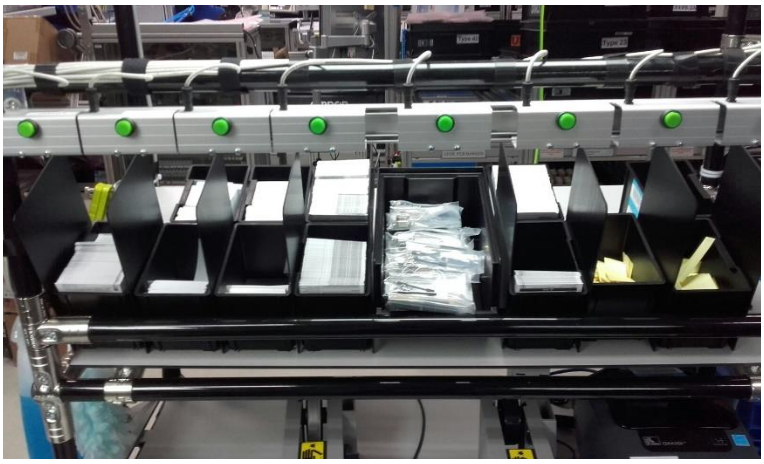

Figure 24: Pick to light system for the booklets and extra components

The CIF-01 gets one extra component within its box, this is a connector that fits on the VGA port.

Figure 25: An unfolded box as they are delivered to the production line

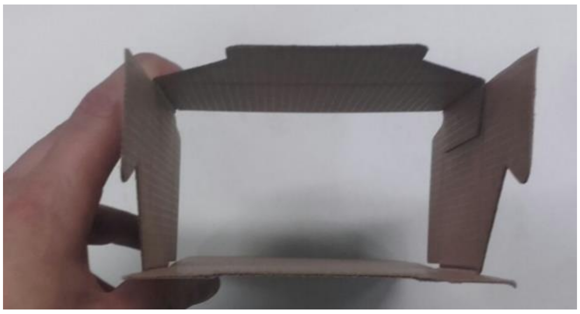

Figure 26: Box after it is wedged and ready to be folded

After the box is folded, the bag with the product can be put inside together with extra components and instructions. The box is then folded shut, ladled on the side and put in a line output box. For the full folding process, see appendix C.

3.17. Full automation of the production line: packing.

This module has some sub processes that have to be completed. The box should be automatically folded and ready to have products inserted. the booklet and component package should be grabbed together beforehand to put it all faster together.

Figure 27: Box ready for closing

3.18. Optimization of production line.

Because the production line is made for operators, it is not yet optimal for full automatization. Many processes should be optimized for automated use before they can be connected to each other. In the remaining time of the internship, there will be discussed with the involved parties when a certain sub process has to be added. This sub process would then make it easier for the automated system to work a product through the line.

Together with the small optimization steps when necessary, there will be made a new line layout because the line can be built around the automated system.

At the end of the internship there will also be an extensive list of recommendation that can be looked at by Omron when they start the full automation of the production line.

4. Project requirements.

The demands of Omron were that the production process should be fully automated. With full automation is meant: that the process cell is capable to assemble and insert all the products in the casing, that the labels can be applied and that the product can be packaged for shipping. At the beginning of the production line there should be a product input and at the end there should be a packaged product. This result could be achieved by either the robotic arm on its own or with intermediate solutions that do certain sub processes.

Because there is a lot that has to happen to realize this, there will be given recommendations for certain options within the production modules if not everything could be automated within the time of the internship.

Therefore, at the end of the of the internship there should be a report with the descriptions of the results and recommendations for the production line. There will also be given a demonstration of the achieved results.

4.1 Problem definition.

Can the casings be bin picked? This will be tested if the necessary equipment and time is available

Is it possible to complete the entire assembly module with only the robotic arm? This will be tested and the results will be described. This will be tested first because the assembly module it the most critical module.

Is it possible to take a label with the robot and place it correctly on the casing? This will be tested if there is time left.

Is it possible to complete the entire process cell with only one tool? Multiple design decisions will be made and tested for this purpose.

What has to change on the process structure in order to make sure that the robot can function correctly? This question will be answered during the testing of the separate modules.

4.2 Automation approach.

There has been looked at automation-ml to describe the intermediate communication and top level processes. Because this production process is a single process cell, it has not been used because the PLC port option could not be used yet and it would therefore not give any more value.

In the beginning of each process that would be automated, there was looked at the possibility if everything could be done by the robotic arm itself. If this was not the case, there would be looked at an intermediate solution to progress the process. This solution would then be simulated within the test module that was built at Fontys and described within the end report.

5. Assembly module result.

The automation was started with the assembly module because this was the most fault critical and challenging module of the entire production line. If the assembly went correctly, then the rest of the production line would be only the product handling. At the start of the automation process has this been discussed with Omron that if this module would be possible that the company would know that this line automation would be possible and that they could start themselves.

5.1. Complete test setup.

The robot that has been used to prove that it is possible to assemble this product is an UR5. This robot has been used because it is the one robot that was currently functioning within the Fontys lectorate. For this test setup, multiple wooden and plastic modules were made to test the capabilities of the robot. For the robot programming, there has been made use of fixed position waypoints. This was chosen because it would mean that if this approach could be used with a reasonable repeatability, the system could be made in such a way that the many different situations would converge into a single homogenic process that was simple yet effective. There has not been made any use of vision although this will be recommended in a later chapter.

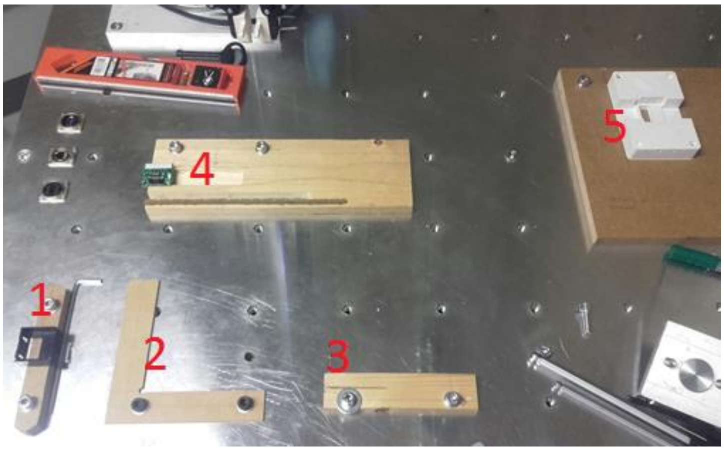

Figure 28: Image of test setup

The test setup incorporates all the aspects that the assembly module would need in order to succeed. The sub modules have been spaced out to make testing easier and will have to be put together in a later iteration of this module. The sub modules of the test setup are numbered in the image so they can be discussed below.

5.1.1. Casing pick-up simulation.

The casing has to be taken out of a bin with a kind of bin picking system in the final module. This is simulated by placing the casing on a strip of wood. The casing can be put anywhere on the strip, so it simulates the many possible pick up orientations that the casing can have after the bin picking. The gripper will pick up the casing anyway, so the orientation has to be adjusted. this will happen in the 2nd sub module

5.1.2. Reference surface.

The reference surface is used to put the casing in an orientation spot where the gripper can always grab the casing with the right orientation. With the right orientation is meant: the position of the gripper on the casing so that the casing can be placed into the assembly JIG. This orientation is achieved by releasing the case near the corner of the reference surface, pushing the case against the side with the inbus bolts, then pushing the case against the side without the bolts and then pick up the case again.

5.1.3. LED guide bowl feeder simulation.

This wooden strip has a small slot that can fit multiple LED guides next to each other just like a regular bowl feeder would. The bowl feeder would simply push the next LED guide to the end of the slot when one of them is taken out. Therefore, this part of the test setup is made with fixed positions.

5.1.4. PCB pick up station simulation.

In this small mall is the PCB placed with a certain orientation. In the final module, there will be something similar because the PCB first has to be broken out of the PCB rack and it cannot be placed directly in the casing with when it is broken out because the gripper will then not be able to place it within the casing. The gripper will pick up the PCB out of the mall with little slots in the gripper fingers. After the pick up, the robot will maneuver the PCB in such a way that is has on one side the teeth of the PCB in the mounting holes of the casing and the other side in the mounting groves of the casing. Then the robot will simply click the PCB in the casing.

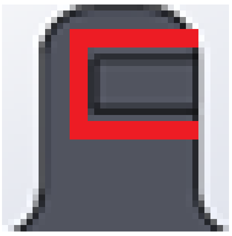

Figure 29: Image of PCB slot on grip finger

5.1.5. Assembly JIG

JIG adjustment and iterations.

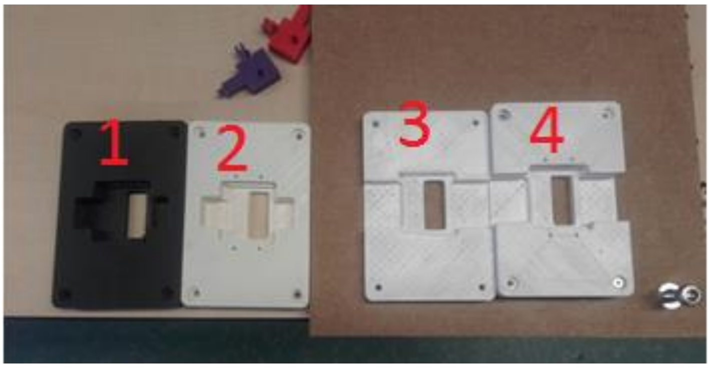

Figure 30: All iterations of the assembly JIG

The assembly JIG is the main station in the assembly module where every separate product has to be placed in such a way that everything Is assembled. The original of Omron did not have enough space for the grip fingers to place the casing. So there has been worked on a new version that satisfied Fontys and Omron demands. This will be discussed below.

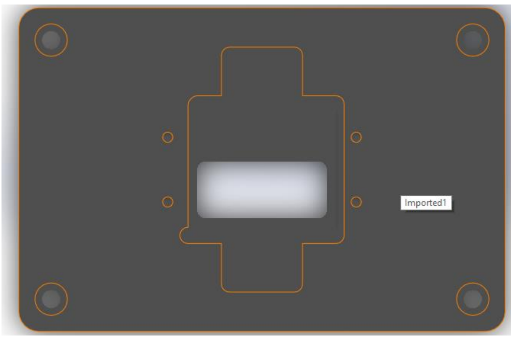

Figure 31: Original JIG

The original.

This JIG is one of the original files that Fontys got from Omron to test the production line with. No adjustments were made and it was 3D printed in such a way that it was as close to the original as possible.

The second iteration.

With this iteration, nothing has happened with the design, it has only been printed in white to make sure there is maximum contrast with the products that have to be assembled in the situation of a vision system. White has been chosen because it generates maximum contrast with the black casings. White could give problems with the transparent LED guide, but this concern was dismissed because the LED guide would be checked against a black background that is the casing where it would be placed in.

The third iteration.

With this iteration, the overall height of the JIG has been lowered and the small bar inside the JIG has been sleeked to make it easier to place the casing inside the JIG. There have also been carved out greater rectangular holes where the finger holes once where. These holes are of course for the robot gripper so that it can place the casing correctly.

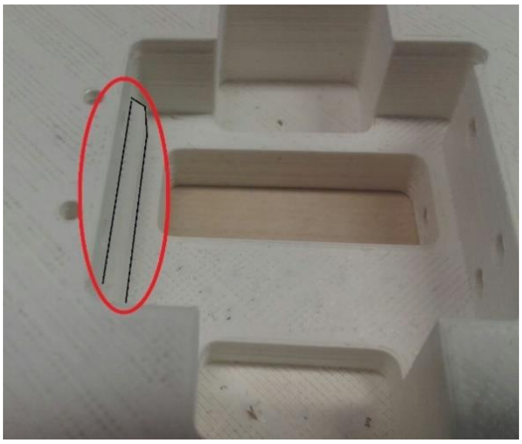

Figure 32: Original white JIG white rectangular bar

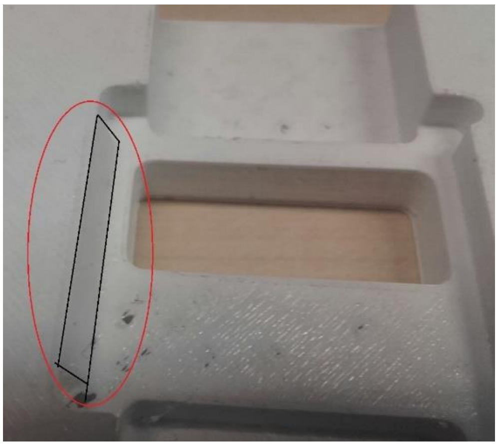

Figure 33: Lowered JIG with sleeked bar

The Fourth iteration.

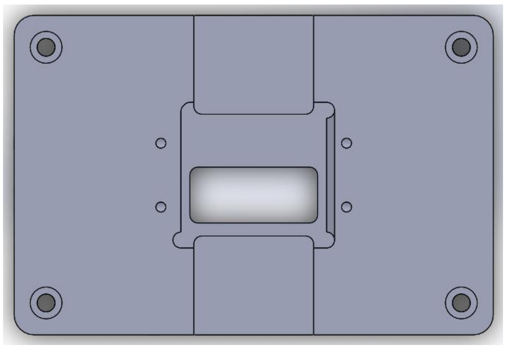

Figure 34: Final JIG design with original height

This is the final iteration and uses the aspects that were deemed necessary by Fontys and Omron. It uses the original height and leaves all the original sensor passions intact. Still, it has the same gripper holes as the previous versions and the sleeked JIG bar. This JIG would be able to be fitted in the production line right away.

5.1.6. The Grip fingers.

Because of the special demand of maneuvering and positioning of the separate products of this assembly, there were multiple solutions on how to assembly this product. There could be a simple tool change for every process but this would take time and would increase the costs of the production process. Instead there was looked at the alternative of multipurpose grip fingers that could do a different task with a different orientation of the robot head. There were made three iterations of this solution. These were made because when the progress was made until the PCB maneuver. The conclusion was that there had to be made a few changes.

First iteration.

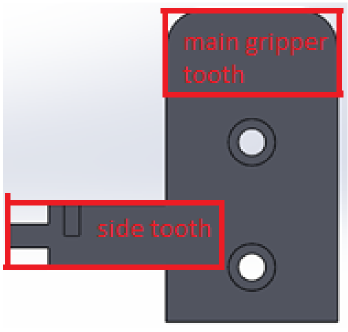

Figure 35: Pinpoint of different grip finger aspects

This kind of grip finger has the ability to pick up the casing and the LED guide. It can pick up the casing with the main tooth and pick up the ledguide with the side tooth. This is achieved by changing the orientation of the gripper head from vertical to horizontal. This worked well until the PCB had to be picked up. After several tests, it appeared that the tilt angle was not possible with the side tooth on the grippers because it would always hit the casing and therefore it was not suited for this purpose.

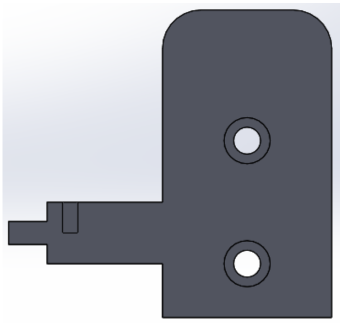

Figure 36: Original grip finger

Second iteration.

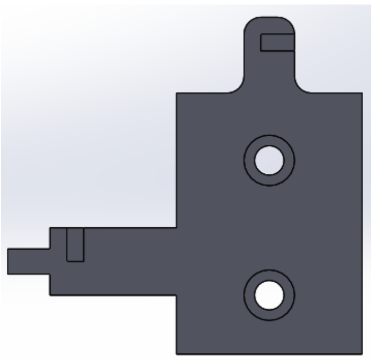

Figure 37: Right gripper part

The second iteration was mainly focused on grabbing the PCB and making sure that we could maneuver it in the casing so we could fully assembly the product. In this iteration, there has been made a cut on both sides of the original grip finger so that the tilt angle can be achieved. Also, a similar slot was fitter in the new pick up fingers like the one that is on the side pickup tooth. Then everything was rounded to make sure it would not hit the casing. The gripper has kept it's length, but is has been given a precision pickup tool for the PCB. These simple slots give it the ability to pick up the PCB, but also put force behind the PCB it when it has to be jammed in the casing of the product. To see the grippers in action, look at appendix …..

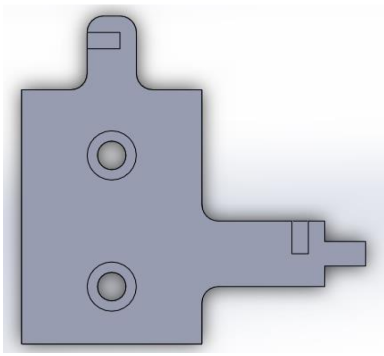

Figure 38: Left gripper part

Third iteration.

The third iteration is based out of personal experience with the material of where the grippers are made from. This PLA plastic grinds down fast and is therefore not a suitable material for the grip finger. The slot become eventually to big and unsymmetrical to make a consistent performance. The eventual design therefore has no slots. This way of working gives the grippers more movability when inserting the PCB. It also gives the gripper an even lower grab point onto the casing. This lower grab point makes it easier to release the PCB on to the guiding slots of the casing because the release fall height is smaller.

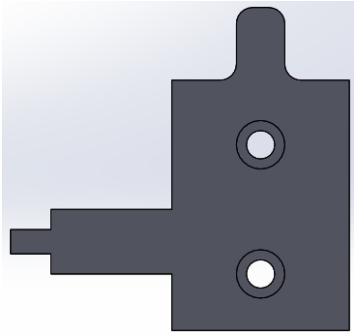

Figure 39: Final grip finger design

5.2. Conclusion.

The assembly module can already be achieved by the simple means of a robot with a single tool. This can already be directly implemented within the process cell. There has to be done a lot of tuning to the efficiency of this module to make it even better. The operator is still far faster than the robot is but that will change with the next iteration of this module. With the test setup, everything is very far away from each other so there is a lot of time lost, this will be the first thing that has to be adjusted.

	robot	operator
picking casing	26	5
placing LED guide	22	7
placing PCB	34	8
	82	20

6.0. Recommendations.

Bin picking system for the casings.

There has to be added a bin picking system for the casings that makes sure the casings are always put in the right orientation at the start of the assembly module. There have been tests with a PICK IT camera and it can detect the casings. There has not been tested how this could be used in cooperation with a robotic arm.

Vision systems to detect PCB’s and break them out.

There has to be a vision system in place to detect and guide the robotic arm to the positions of the PCB break out rack and break the PCB’s out. This could already be achieved with a 2D contour detection system that detects the edges of the PCB’s and the break out rack’s. This could be done with a vision camera and software.

Vision system to detect if the products are fitted correctly in the assembly JIG.

Above the assembly, JIG there could be a setup fitted with a 2D vision system. This could potentially detect mistakes and instruct the robot to remove a product or repeat a certain maneuver.

Testing module dip switch changing.

At the testing module, there has to be a system that has some kind of pincer that can shift the dip switches on the CIF-11. This system should can interface with the checker system so that it knows when it has to shift the dip switch.

Labeling approach at the labelling module.

There has to be a system in place in the labelling module that is either able to directly place the labels on the casing or make sure the robot is able to. Furthermore, the labels have to be checked when they exit the printer if the quality of the labels is sufficient to proceed. This could be done by some sort of vision system or line sensor that scans the label when it exits the printer.

Other possibility for product handling.

There could be the possibility that the gripper fingers that were designed are not up to the task for the entire process cell and has to be replaced by a different solution. This could be done by a robot that switches tools. The first would be some kind of pincet for the LED guide and label. The second tool would be the regular gripper for handling the casing and PCB.

Assembly module alternative.

For the assembly module, there could also be chosen for a different assembly system that simply gets the sub-products inserted and then assembles the product by itself.

Packaging module recommendations.

There has to be a system at the packaging module that collects all the parts and manuals that have to be inside the box of the product. This could be done by some kind of slide system that simply collects everything at the bottom so the robot can pick it all up and put it in the box.

There has to be some system that pre-folds the boxes where the products have to be packaged in. this could be done by some kind of automated setup mall that automatically folds the boxes when they enter.

7.0. Answer to problem definition.

Can the casing be bin picked?

Figure 40: a bin with CIF casings

Yes, this would be possible because the PICK IT camera that is available at Fontys can detect and differentiate them from each other. The way they are stacked in a bin does play a role however. If you can have them more organized like in the image, it should be possibel to pick them up with a standard gripper part like the one that was used in this project to make the CIF because it would be able to grab the casing by clamping it in the big port slot.

Is it possible to complete the ntire assembly module with only the robotic arm?

Yes, this is possible and this has been tested and confirmed in video footage. It should be used together with vision to make sure that this process has the maximum fault detection and will function as near perfect as possible.

Is it possible to complete the entire process with one tool?

This is inconclusive because there was not enough time to build every module. Still, for the entire assembly module this is possible. Therefore, it could also be possible that with some minor adjustments, this same tool could be used for the rest of the process cell as well.

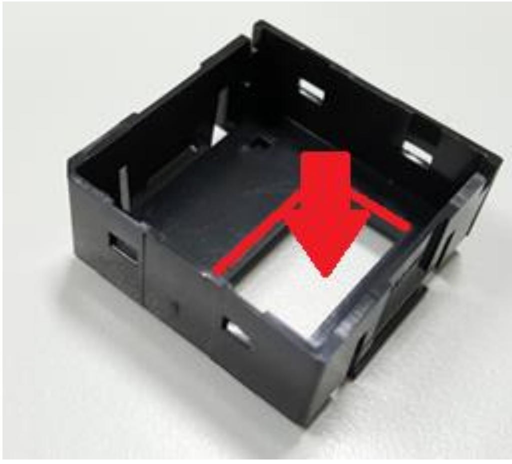

Figure 41: Instruction representation of where the communication port should go.

Is it possible to take a label with the robot and place it correctly on the casing?

There was not enough time to test this. However, the tool that has been developed for the assembly module could be able to do this task as well with some minor adjustments. A recommendation here would be that the developed gripper tool would be made out of steel and that the ends of the side tooth would be shaped into something more similar to a pincet.

What has to change on the process structure in order to make sure that the robot can function correctly?

For the production line structure, there could be added some kind of pre-assembly phase were everything is collected out of the production input bin for the casing and the PCB break out rack. Other than that, the process cell structure is already ideal for full automation.

8. References

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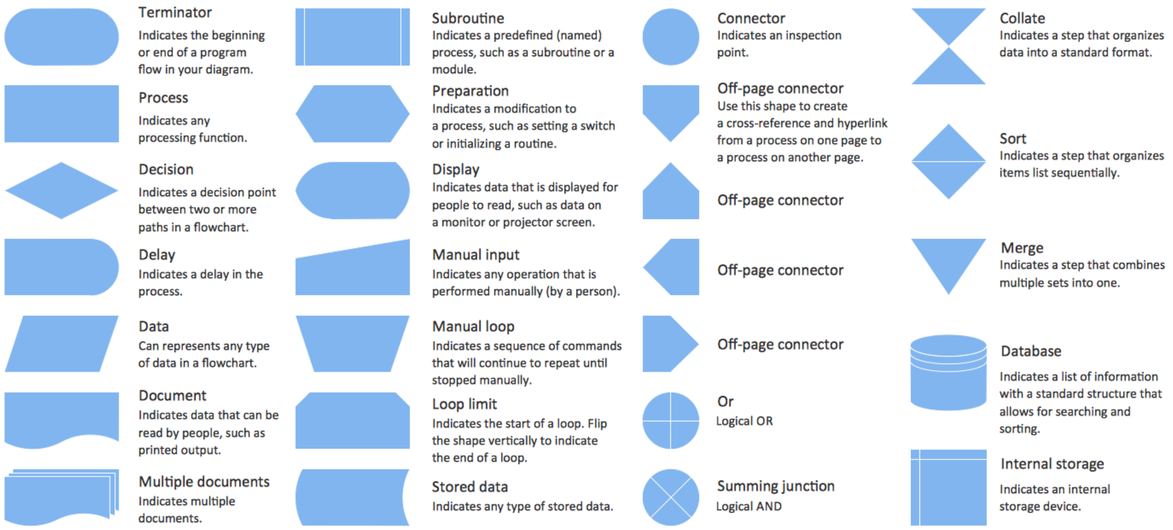
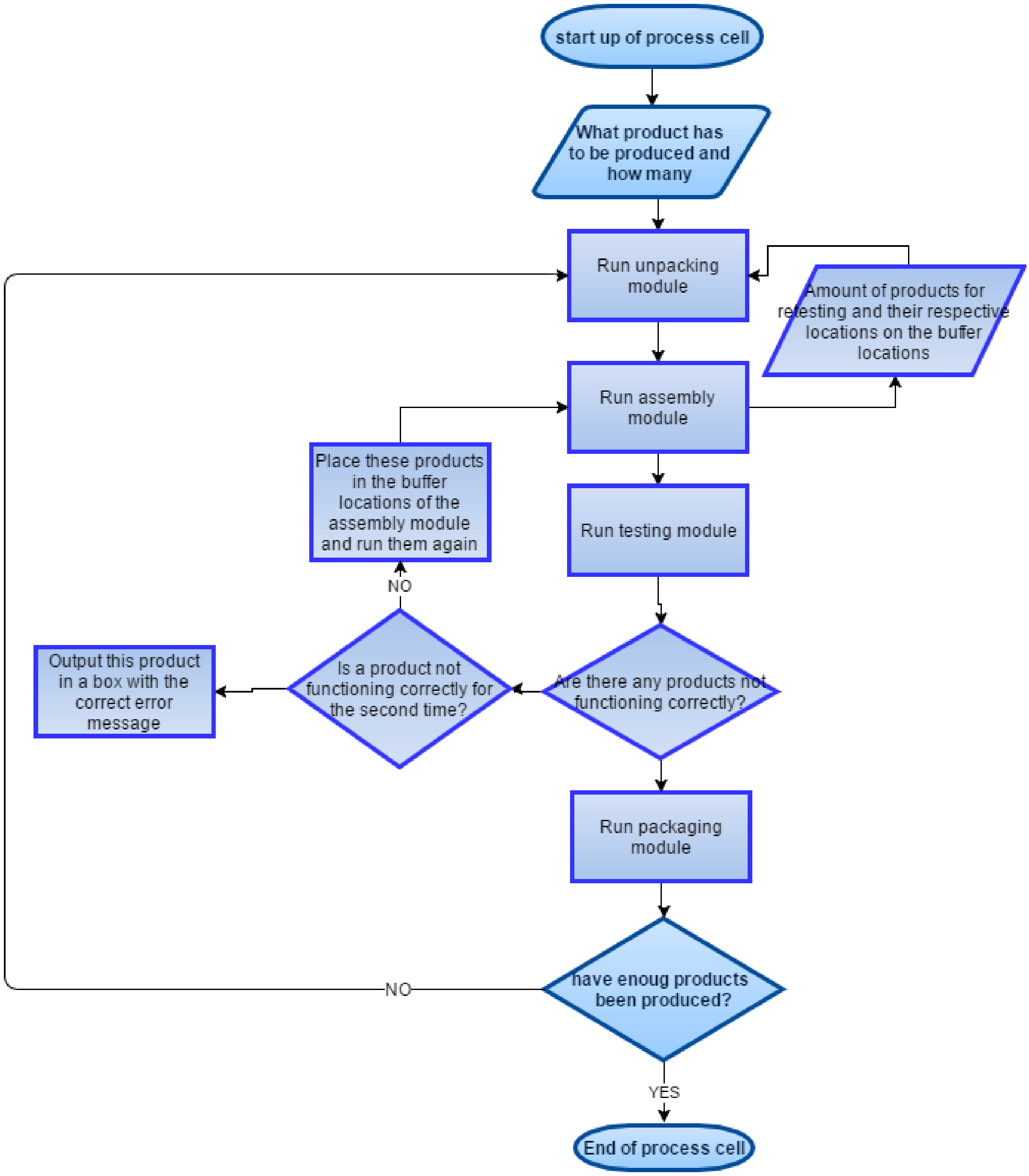
[5] Moss Kanter, R. (2000). *Collaborative adventage*. 1st ed. [ebook] Available at: http://s3.amazonaws.com/academia.edu.documents/33326914/Collaborative_Advantage.pdf?AWSAccessKeyId=AKIAJ56TQJRTWSMTNPEA&Expires=1475679728&Signature=2%2B3m59r1Paw3%2FP%2Fs9K7JJk35NEs%3D&response-content-disposition=inline%3B%20filename%3DCollaborative_Advantage.pdf [Accessed 5 Oct. 2016].

[6] http://www.conceptdraw.com/examples/flowchart-symbols

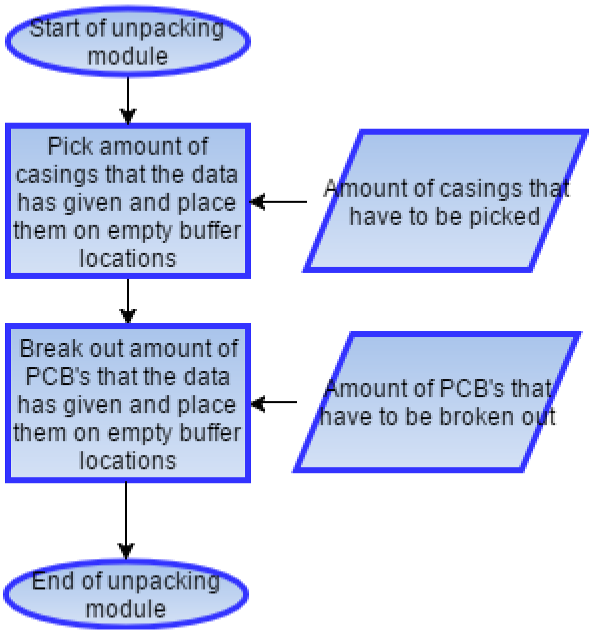
Appendix A: Process charts of production line



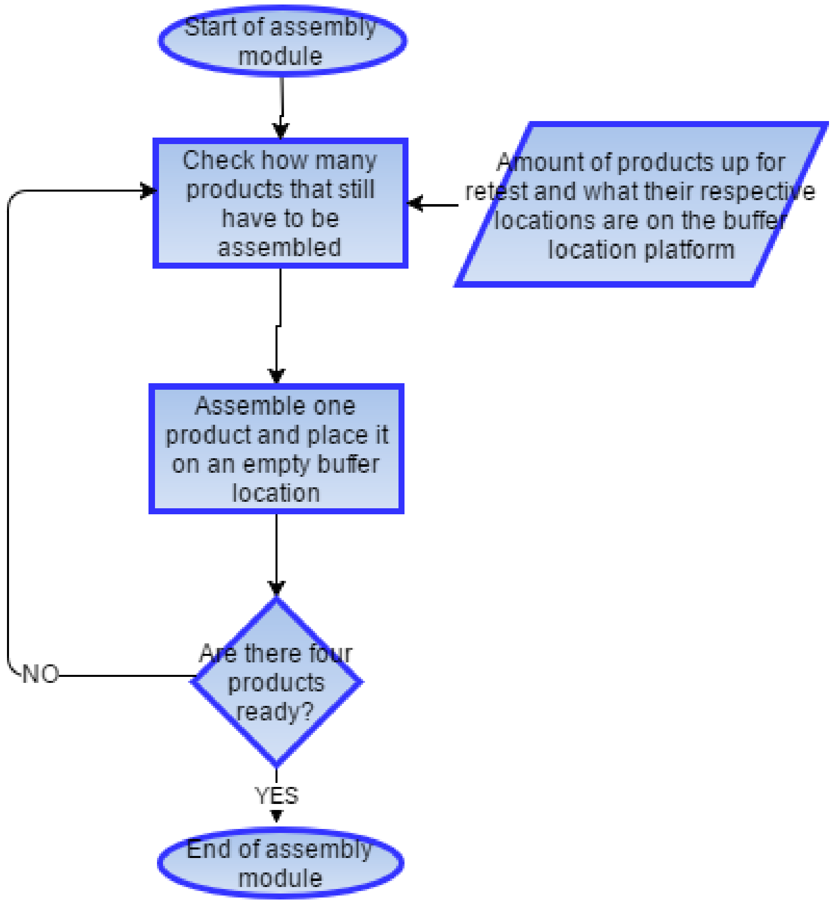
Explanation of the symbols that are used within the process charts. [5]



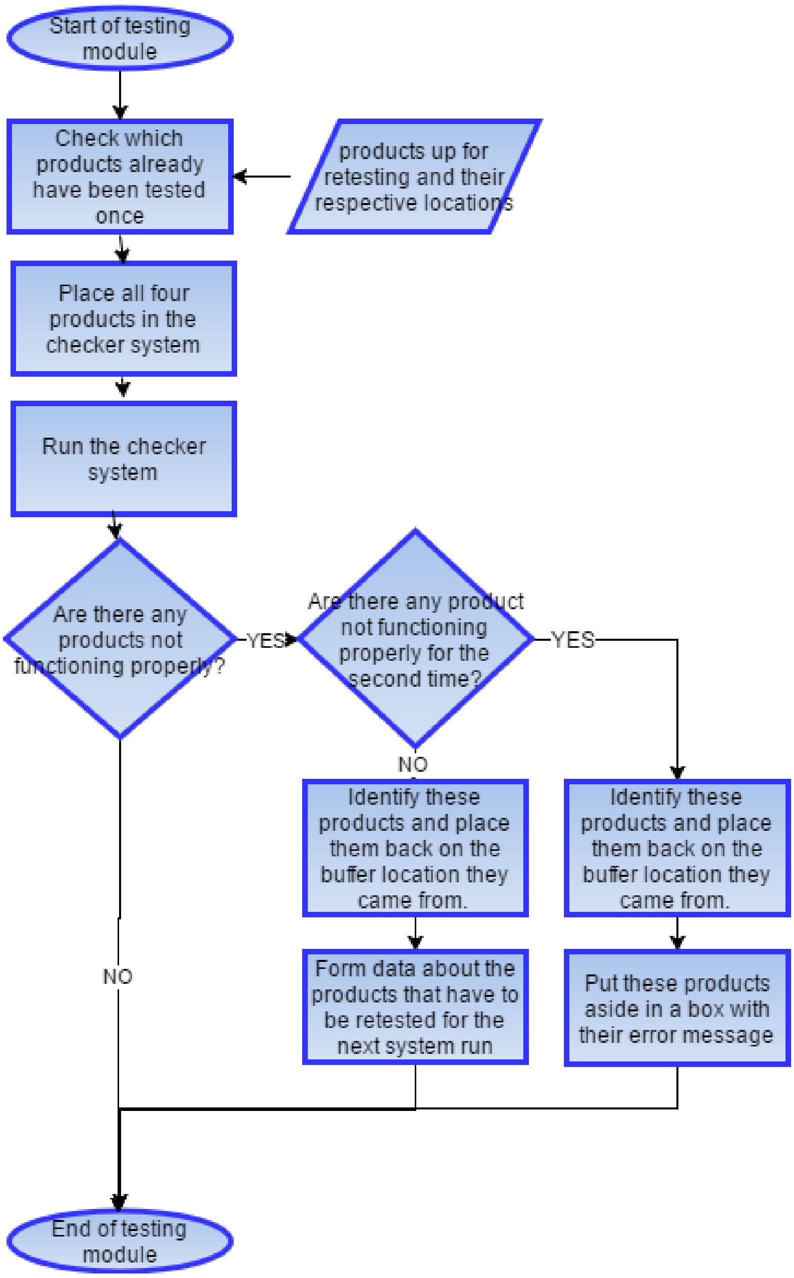
Process chart of the entire production process.



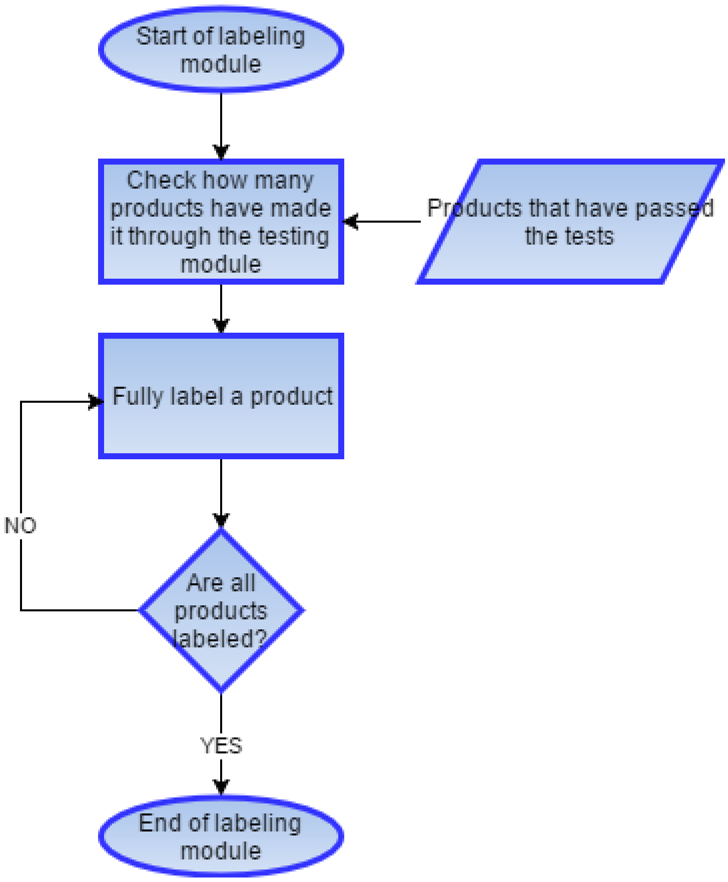
Process chart of the unpacking module



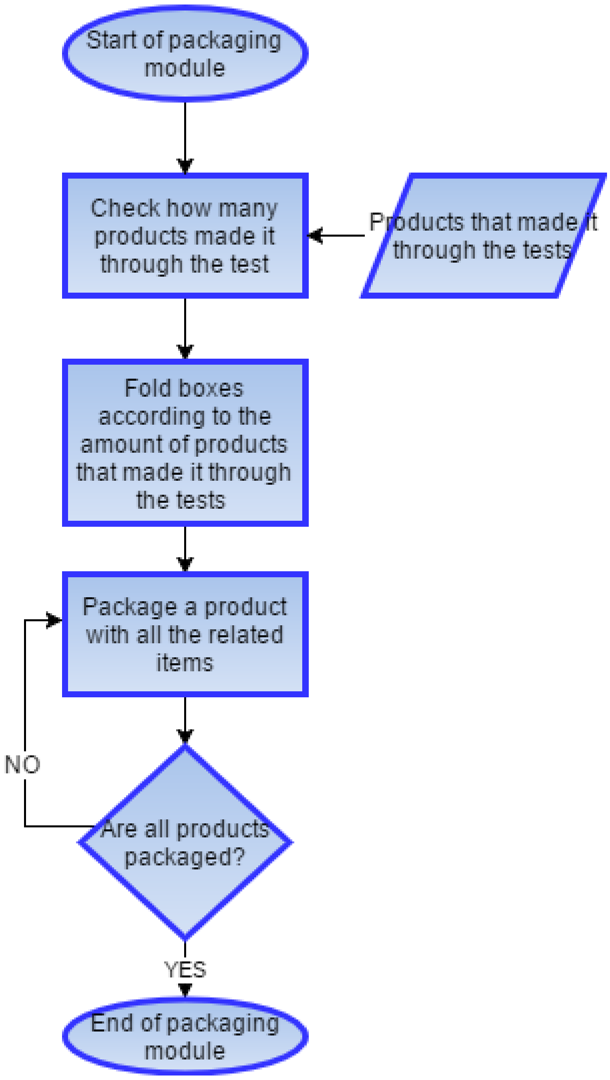
Process chart of the assembly module



Process chart of the testing module



Process chart of the labelling module



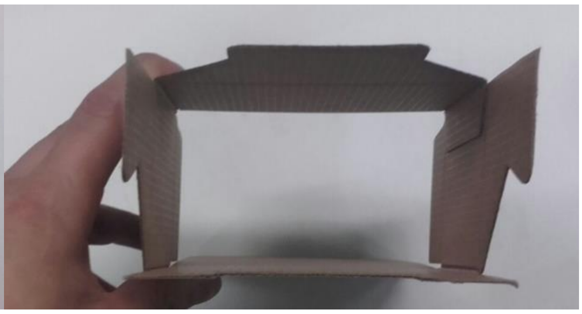
Process chart of the packaging module

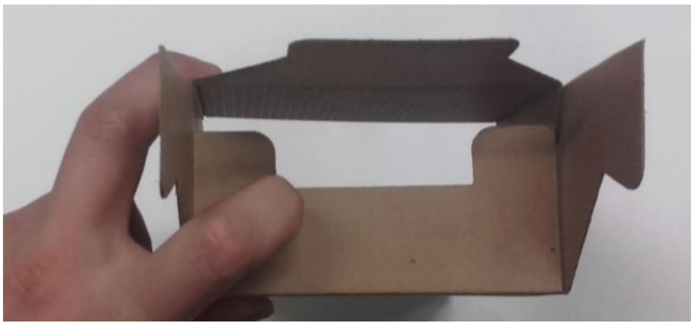
Appendix B: CIF-11 test sequence

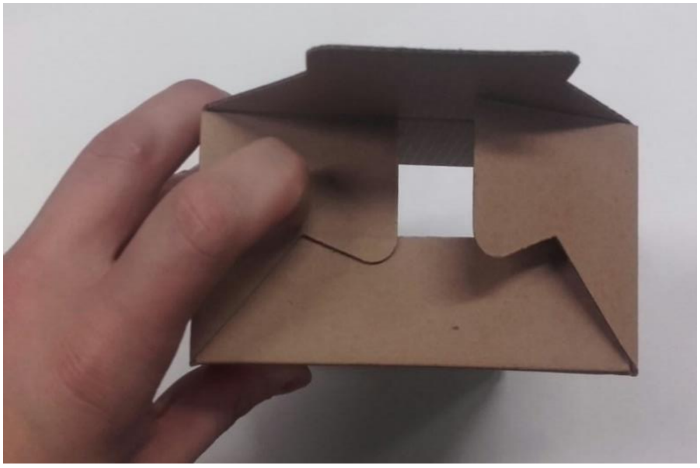
The next sequence is prefomed on the dip switch of the CIF-11

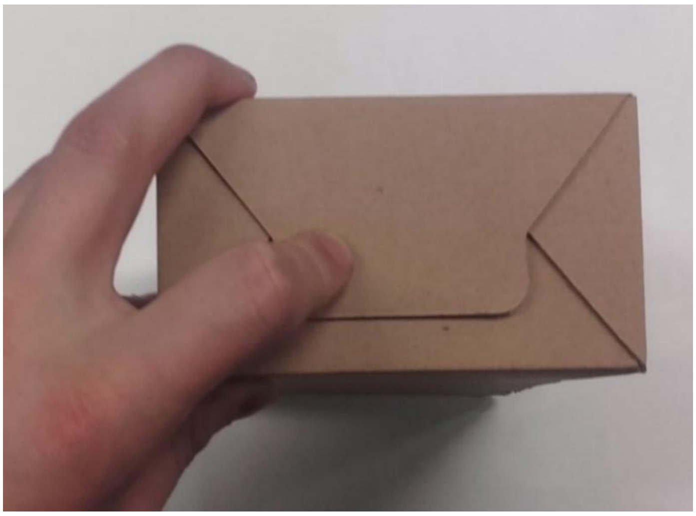
Put switch 5 up.
Push Green button to proceed.
The checker will run the next set of the test program.
Put switch 2 and 3 up.
Push Green button to proceed.
The checker will run the next set of the test program.
Put switch 5 down and put switch 6 up.
Push Green button to proceed.
The checker will run the next set of the test program.
Put all switches down.
Push Green button to proceed.
The checker will run the next set of the test program.
Put switch 1 up.
Push Green button to proceed.
The checker will run the next set of the test program.
Put switch 1 down.
Push Green button to proceed.
The checker will run the next set of the test program.

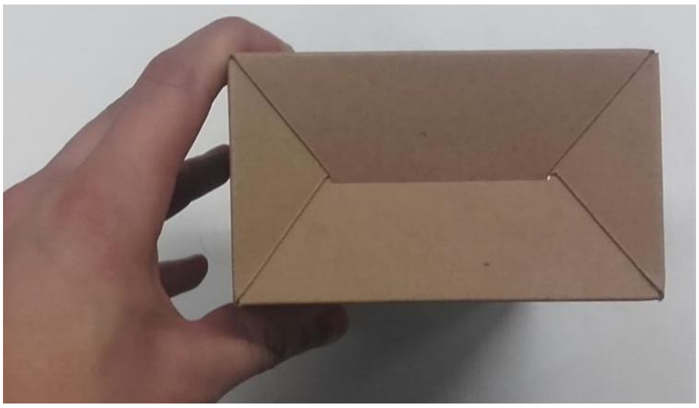
Appendix C: Process of folding the product box

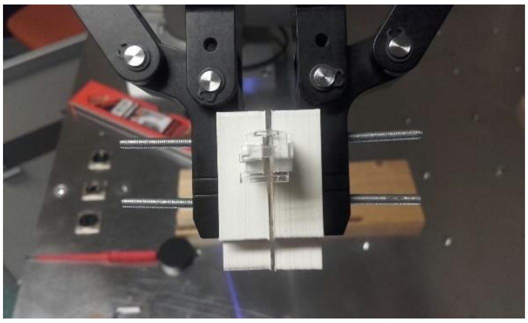




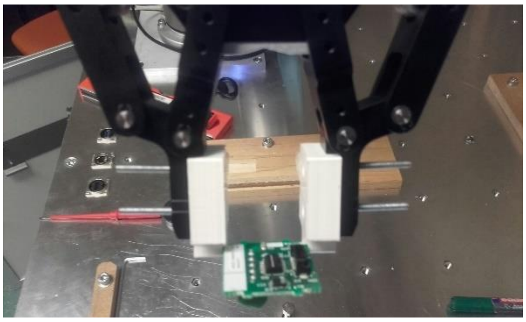




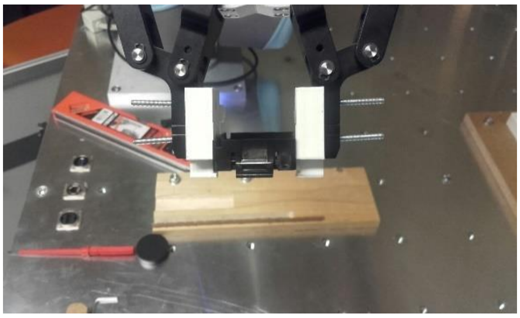
Appendix D: gripper in different positions with different sub products



Gripper with ledguide

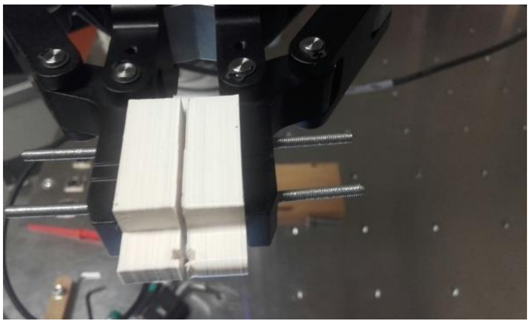


Gripper with PCB



Gripper with casing

Gripper open



Gripper with ledguide, In the assembly position