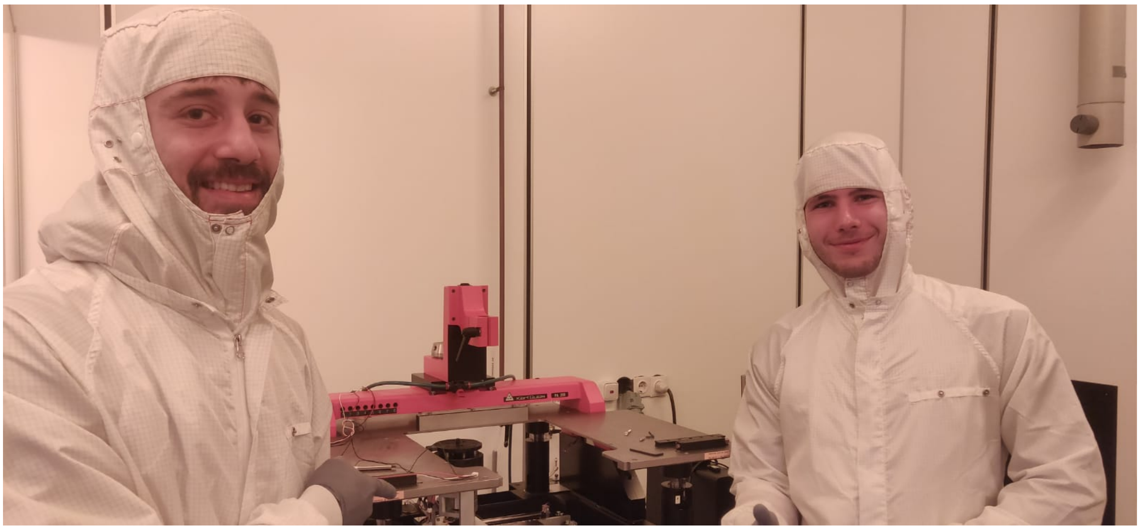
Personal Development Portfolio and Justification of Research Activities



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1 Introduction

My name is Stelios Diamantopoulos, and I'm a third-year student of Electrical and Electronic Engineering at Saxion University of Applied Science. In the upcoming semester, I'll be working on an intriguing project in the Nanotechnology Lab at Saxion, which involves optimizing the data generation process for increased prediction accuracy in a specific model of MEMS device.

Our team recently received valuable documentation from a former student who is currently pursuing a PhD. The documentation outlines a pipeline that entails generating artificial data with random defects for the MEMS device of interest. This data is then used in conjunction with a machine learning model called YOLO to visually inspect real MEMS devices and identify the primary defects present.

As part of our project, our team has the important task of fine-tuning the data generation process to enhance the accuracy of defect predictions. This optimization process requires adjusting various parameters that are specific to each of the four primary defects we encounter: particles, decoloration, membrane, and missing trace. By identifying and adjusting these parameters, we aim to improve the quality and effectiveness of the generated data for training the machine learning model.

While my background primarily lies in Power and Automation, I have dedicated the past few years to developing my programming skills. Recognizing the growing significance of machine learning, I have actively worked on strengthening my Python programming skills, which I believe will be instrumental in successfully carrying out this project.

Our project kicked off with a productive meeting involving our supervising teacher and the client. Right from the start, I had a clear idea of what I wanted to focus on within the project. I communicated my intentions to both my supervisor and the client, and I was pleased to receive their positive response and support. Of course, the final deliverable and the scope of the project will be continuously refined and adjusted based on ongoing discussions and feedback from all stakeholders involved.

2 Personal Development Portfolio

2.1 Applying knowledge and skills & Responsibilities(criterion 1,3)

Throughout this project, I figured out that my domain knowledge from Electrical Engineering such as circuit design and signal processing was not very relevant to the project instead, I had to deal with a lot of programming something that I became familiar with in the 1st semester of my studies where Electrical Engineering and Computer Science coexist. Having that superficial knowledge about programming helped me a lot to understand how to create my own scripts. Also during my Minor, I had an internship for a company regarding data quality so I had to deal with a lot of data thus python became an essential tool for my everyday work and that is something I want to enhance during this project. To make the reflection process easier I setup 3 technical learning goals skill.

1. Goal: Create ML Pipelines for Training different models.
2. Goal: Evaluate different ML models
3. Goal: Get to know more about good coding practices and codebase sharing within a team.

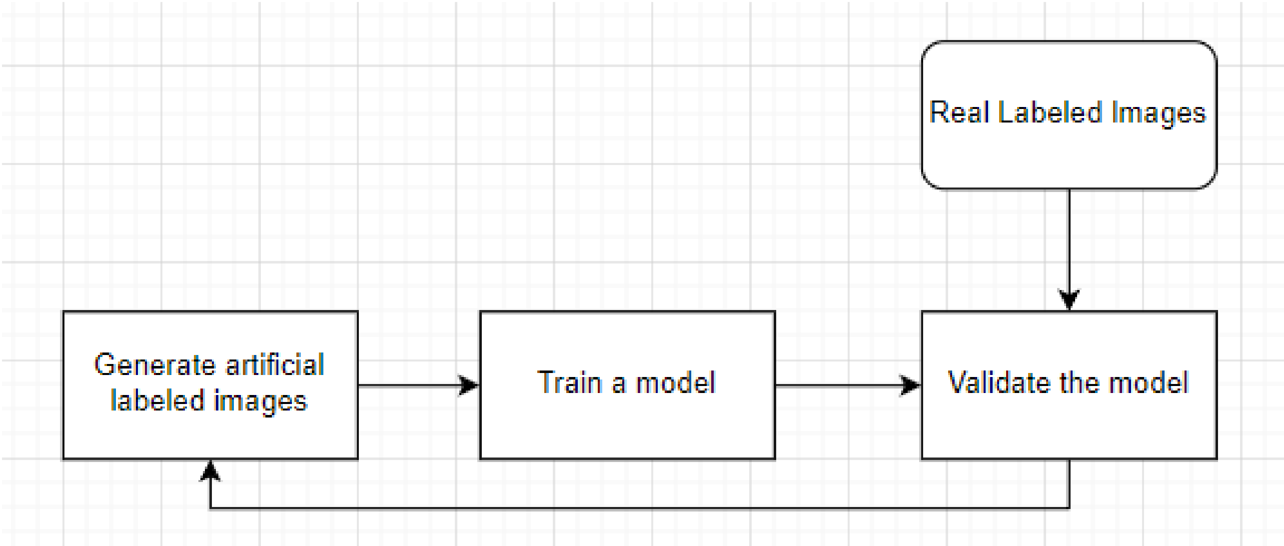

Figure 1: Pipeline Setup

2.1.1 Create a Pipeline for training and validating a ML model

Training and validating a ML model can be a tedious and time-consuming task. There are a few steps in the process for doing so .

Generate Synthetic Dataset
The first part of the process has to do with gathering and labeling images with the specific defect that we want to detect with the ML model. In our case, we were lucky because a previous student had already developed a script that we could use in order to generate artificial particles as defects, on the other hand, we had to deal with a code that was developed 3 years ago and the codebase director did not follow good coding practices. Fortunately, the codebase had a UI [10] that we could use to explore the generation process. Finally, after experimenting with the UI and the generation process we decided to strip the front end from the application and use the backend as the backbone of our script.
Train Model Using Yolov8
After we acquire the images for training we had to train an ML object detection model. Our preancestor decided to go with YOLOV3 from Ultralytics. You Only Look Once (YOLO) is one of the most used forms of machine learning when it comes to object detection because of the simplicity in combination with its widespread use like Du [3] and Jiang, Ergu, Liu, Cai, & Ma [6] reported. Another advantage is that it is better in detection than other commonly used forms of AI [9], but Liu, Hu, Chen, Guo, & Ni [7] show that when you combine YOLO with other forms of AI, the results will be slightly better. When looking deeper into which forms of YOLO are the best to use, Atik, Duran, & Özgünlük [1] suggest that YOLOv3 might be a good version of YOLO to use; however, they don't take newer versions into consideration. Because the newer versions of YOLO perform better than the older ones, as seen in the research done by Liu, Hu, Chen, Guo, & Ni [7], it was decided to work on using YOLOv8 models.

1. Backbone: A convolutional neural network that aggregates and forms image features at different granularities.
2. Neck: A series of layers to mix and combine image features to pass them forward to prediction.
3. A series of layers to mix and combine image features to pass them forward to prediction.
4. Yolo models offer an architecture were you can train it Custom dataset.

The ultralytics GitHub repository contains all the information regarding the different YOLO modes as well as instructions on how to use yolo with a custom dataset.

Code Development
At this point developing the script to train the model is pretty straightforward.

1. Create the proper file structure for training which means creating the proper folders with the appropriate names and splitting the data in validation and train datasets.

   link:Split data script

2. Develop a script to initialize the training.

   link:Initialize training

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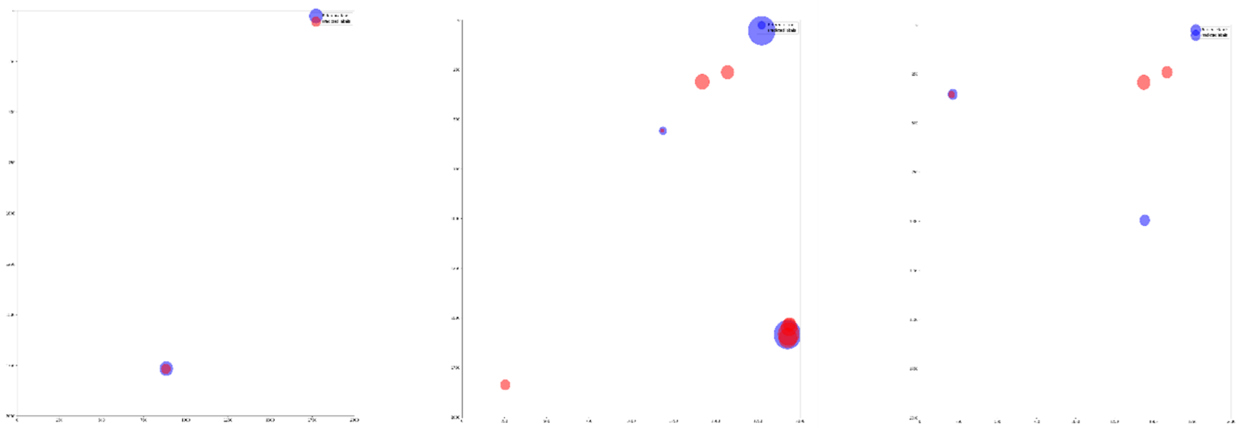
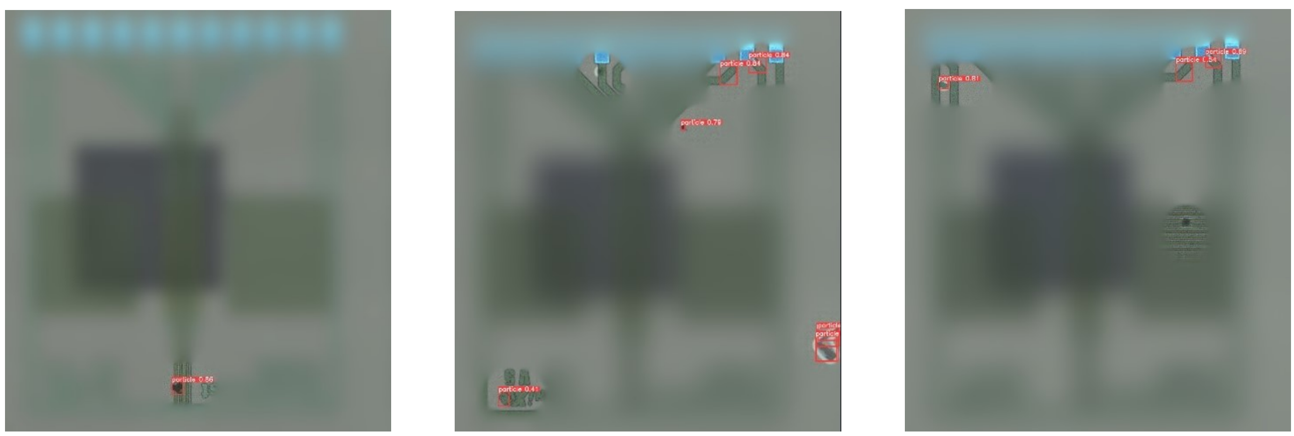
2.1.2 Evaluate different Machine Learning Models

Automating the evaluation process is more challenging than we thought in the first place. The metrics that we had regarding the loss function and the accuracy scores even though they were results we could not use them for comparing different models. Because of the complexity of the problem here, our team developed 2 different approaches to this problem, personally, I contributed to the 2nd one so that is the one I am going to write about. For the evaluation process, we have a dataset of 60 images with real defects and the corresponding labels. We use a script to test our model on each one of the 60 images thus now we have the 'original' labeled dataset and the 'model output' label dataset.

The labels used by YOLO for defect identification include the variables X, Y, Width, and Height, along with the size of each image. To overcome the challenge of visualizing data in four dimensions, we made a modification by combining the Width and Height variables into a new variable called Area. Consequently, we now have three variables: X, Y, and Area. To assess the accuracy of the model, we devised a sophisticated bubble chart where the X and Y axes represent the actual image size, while the defects are scaled based on their corresponding Area values. This visualization allows us to visually evaluate the model's performance, as a desirable outcome would involve overlapping between the reference and predicted labels



(a) Evaluation for Image 1 (b) Evaluation for Image 2 (c) Evaluation for Image 3



(d) Image 1 (e) Image 2 (f) Image 3

Figure 2: Model Evaluation Output

For future recommendations, a spectrum analysis could potentially automate the process. Meaning that the overlapping will produce a purple color in this case which we can use to evaluate the model.

2.1.3 Get to know more about good coding practices and codebase sharing within a team.

Here I have to give credit to my teammate Camiel as he was the one being more experienced in good coding practices. During the project he orchestrated us to work under the same codebase, he created a GitHub repository for us to share code and models. Also, he gave us a 'masterclass' on git and GitHub basics which was fantastic. When you share code with other people it's important to keep your git history clean and well documented, whenever someone pushes a code change it is expected him to commit a message as well describing the changes that he made as well as the reason for this change. Keeping track of the Git Commits Messages we were able to recreate the storyline of our code development just by creating a script that takes the git messages and summarizes the workflow for us.

Git Commit History

Our team has developed a script that extracts the git commit messages with their relative timestamp. We have sorted and summarized these messages by using ChatGPT automation to extract the progress out of our commit messages. We have extended the responses to elaborate a bit further on our progress on a week-to-week basis.

Week of March 20 The project was initiated with the setup of the basic necessary files like installation scripts, codebases, reference images, and adding the code from the program made by Romas as a library. The image generation library was debugged while the program was stripped from its front-end and integrated into our software. After we were able to generate images from our own software, we added image conversion from SVG to PNG to use with machine learning training.

Week of March 27 This week we added the integration between generating training images and added a conversion layer for storing the labels in YOLO format. Another part that we added was the creation of scripts for data handling (removing generated images & cache) and we ran a YOLO training session with test data. Adjustments were also made to the code to clean up outputs and improve data organization (such as saving labels to a separate folder and saving to a training folder). An SQL structure file for centralizing training data was also created.

Week of April 3 It was during this week that we started integrating the training pipeline. We extended our pipeline by adding code that tests the trained model on reference images. Other modifications include integration with an AWS Postgres database and adding an opacity option to the image generation process. We also worked on enhancing the training process, such as auto-starting the training and adjusting the number of epochs.

Week of April 10 After the first few trainings we did on our laptop (with a small dataset and a low number of epochs), we concluded that CPU training is very time-consuming. We decided to follow the best practice approach and integrate GPU training into our pipeline by setting up a PC that had a GPU with a Linux-based operating system (Debian). This PC is a personal device that has been set up by one of our developers to be used during the development phase. After the training, the images are deleted, and the model performance could be stored in the Postgres database at AWS. This cloud-based approach to machine learning model development is the industry standard.

Week of April 17 After a mid-term presentation, we revised the training parameters and generated a 55GB dataset with varying particle parameters to imitate the wide range of particle defects that can be encountered during production steps. To our surprise, the expanded dataset size and extreme variance in defect properties did not yield a higher-performing model. We explored the idea of creating sub-datasets with small, medium, and large defect sizes. After fine-tuning the parameters for each of these three categories, we aim to merge them into a single dataset.

Week of May 8 We prepared our pipeline for training another model and cleaned up the test data names and labels. We discussed re-labeling the reference images but decided to meet with Romas and Aleksander first to receive their feedback about our progress.

Week of May 15 We worked on extending the validation part of our training pipeline with matching labels from our reference images with the model predictions to see how well the model performs.

Week of May 22 There were no commit messages for this week due to the May holiday.

Week of May 29 Significant work has been done to improve the plotting functionality, including configuring plot axes, adjusting figure sizes, working with subplots, and creating bubble charts. A system has also been set up to store labels in a dictionary.

Week of June 5 The focus of this week was primarily on testing and validating the code. The test.py file has been renamed to validate.py. A function for removing evaluation plots was added, and adjustments were made to plotting bubble charts. Additionally, the code for handling file logic related to the bubble charts has been cleaned up.

Week of June 12 A new script was created for transforming reference images into training data. More documentation was added to validate.py, and a non-pip requirement, pycairo, has been removed.

2.2 Professional communication (criterion 2)

Good professional communication skills are crucial for effective collaboration, building relationships, and resolving conflicts in the workplace. They contribute to career advancement by enhancing reputation and opening up opportunities for growth. Additionally, strong communication skills are essential for client satisfaction, leadership effectiveness, and personal branding, ultimately impacting your professional success. As before in order to make the reflection process easier I decided to set up 3 goals when it comes to my Professional communication skills.

1. Goal: Enhancing Verbal Communication in Professional Settings
2. Goal: Enhancing Presentation Skills
3. Goal: Integrate AI Copilot into my workflow

2.2.1 Enhancing Verbal Communication in Professional Settings

Personally, I believe that communication is a skill, and like all skills, it needs exposure in order to be sharpened. I would like to improve my ability to articulate ideas and information confidently and clearly in professional settings, paying particular attention to tone, language, and non-verbal cues. In order to achieve that I forced myself to attend as many meetings as possible, I participated in almost all weekly meetings with the research group and visited the facilities both in Saxion and UT.

Furthermore, during the weekly meetings, I was trying to be as active as possible, which means that I was anticipating my 'moment' during the meeting round where everybody reports on their progress and share anything related to his field of expertise. Some of the activities that took place during the daily meetings were:

1. Update on Project Progress

   During the update, I discussed the progress that we have already made up to this point, identify some of the roadblocks as well as decide on possible next steps that we have to take.

2. Feedback moment for crucial Presentation moments

   I remember 3 moments during the project period when we had to present to the project team in order for them to give us feedback. Some things that I recall from the feedback are confidentiality, vocabulary, and results visualization issues.

3. Random Information

   Something that I loved doing and I think it's nice for every team to do as a tradition is the sharing of 'random knowledge' for example during our project a great breakthrough in the image generation process catch my attention. The product that was developed [11] can easily generate pictures with from an original image with defects with minimum human input. So I decided to take 5 min to introduce the concept to the team. Unfortunately, the team leader did not share my enthusiasm about it.

All in all, I tried to actively speak when I had the floor to express myself and my thoughts which is part of why I sound too critical sometimes

2.2.2 Enhancing Presentation Skills

Presentations Skills are really important and can really make a difference when it comes to performance in a work environment. If your team believes that both your communications and presentation skills are one of your professional characteristics then it is very probable that you will be entrusted with bigger and bigger projects. In order to enhance my presentations skills I took some actions:

1. Create the Original Presentation document

   In the very early stages of the project, I created a presentation regarding MEMs devices, what they are how they are used nowadays, and the general idea behind our project. That was useful because later on this presentation was used as the base for every other presentation we had, thus the looks fonts and logos were the same across the different versions of the presentation we created.

2. Read your auditory & Practice

   During my Minor I had the opportunity to attend some lectures at Berkeley University in California, there I had the opportunity to hear some of the best practices when it comes to presentation skills. There are 2 things that make a presentation good. First is the content, but also the presenter himself plays a crucial role. When I give a presentation I want to be able to adjust to my auditory expectations without adjusting the presentation every time. For example, when we had to give the rehearsal presentation to the team I could see in their faces that there was no reason for the introduction of our student team as we already knew each other, on the other hand at the SEFI conference I could see that people really like the visual we had for the YOLO so I decided to PAUSE in that for a while.

   Practice makes perfect, something that I discovered after presenting a lot of times the same presentation, is the fact that when you have prepared correctly for a presentation you have some space to look at your audience. In fact, it was the first time that I gave a presentation to a 'difficult' auditory and I was not nervous, I knew what I had to say, and when thus I had time to look for clues in the audience regarding the presentation and adapt accordingly.

3. Being proactive and try to present as much as possible to difficult audiences

   On May 24th we had to give a 10 min presentation regarding our assignment to SEFI conference. The SEFI[5] Annual Conference is a scientific conference focused on Engineering Education and the biggest event of this type in Europe.

Figure 3: SEFI conference

   Although the picture is not the best as it looks I play with my phone I am not, I have to say that the conference was a very nice experience for both of us that had the opportunity to present, people were interested in our work and especially in the AI part and the object detection algorithms, moreover we had the opportunity to address the problem of lack of computing power directly to the advisor board of Saxion which was also something that I believe is worth mentioning.

2.2.3 Integrate AI Copilot into my workflow

As mentioned in the beginning I actively tried to have an assignment regarding AI. One of the reasons was that after the chatGPT[10], and other AI copilot assistants like GithubCopilot[4]. As this technology is fairly new, there is a huge discussion about the best practices, throughout this project, I had the opportunity to integrate both of the AI into my workflow, and now that the project is about to end, reflecting on the usage of that 2 AI copilot I believe that they are incredibly useful tools but there is always a drawback when you use them.

ChatGPT3

ChatGPT is an LLM model, basically what it can do is produce text based on a given prompt, in my personal opinion ChatGPT is not an unsupervised model, what I mean by this is that you have to extensively and critically evaluate the outputs. It is a common tactic to use ChatGPT3 to paraphrase your original text, which is something that I tried for my PDP and JORA documents. Even though the results look promising to me, after receiving the feedback for my docs I came to the conclusion that ChatGPT answers are superficial and full of filler words mainly adjectives that on the one hand make the text look more professional but on the other hand the produced is hard to understand as it misses context most of the time.

Another usage of ChatGPT3 had to do with programming, since GPT3 came out I use it most of the time instead of googling or TensorFlow search. I am happy to say that the results are really nice and the potential is huge as it can write code snippets for you in an instant as long as you can very clearly formulate the functionality you want. The results are really promising although you might have to do some debugging in the output code snippet.

Finally, I used ChatGPT3 in order to generate layouts for different report styles, which helps me figure out the topics that I want to include as well as a structure that I can follow in order to finish the report.

Github Copilot

Github Copilot is another Ai tool that I used extensively throughout this project, this tool is like the magic wand of programming, while you are developing a piece of code especially if you do have not the best programming background you are going to be in a position that you will have to extensively write a line of codes with small differences. Copilot is here to save the day for you by analyzing the given line it can automatically generate the required code snippets for you.

Furthermore integrating GitHub copilot in a team workflow can achieve consensus on good coding practices between the team members which is useful, especially in teams with a lot of programmers.

All in all, I believe that AI is going to play a crucial role in the future, as professionals we have the obligation to know how to work with these technologies and understand their limitations and risks.

3 Justification of Research Activities

3.1 Reflection on choices for individual research activities

As a team, we decided to work with an Agile[8] methodology. Agile is a methodology that is mainly used by software developers, it is a feedback-based approach where a task in the front log is developed, then a feedback session is happening and later the changes based on the feedback are implemented in the codebase. Then the cycle starts again until the end product is sufficient and aligns with the client's requirements. In our case, Agile gave us space to work independently, more in the research phase and less in the developing phase. One of the biggest challenges in the early phases of the project was to start training using custom data. First things first, as an engineer, I try to avoid reading extensive documents, on the other hand, I really enjoy following tutorials, I think this is because of the practical mindset we have developed through engineering education. Instead of reading papers and documentation on how to initialize the training I chose to follow some tutorials about Custom Object Detection using YOLOv8.

1. Complete YOLO v8 Custom Object Detection Tutorial | Windows & Linux
2. Deep Drowsiness Detection using YOLO, Pytorch and Python
3. How to train YOLO v3, v4 for custom objects detection | using colab free GPU

After I successfully followed the tutorials I was pretty confident that I knew how to start the training for our custom detection model. So a script for training initialization was developed. Afterward, that script was shared with my team small changes needed to happen regarding the training infrastructure, when I developed the original script on my personal computer I used a CPU on my local machine to train, unfortunately, CPUs are not meant to train models like YOLO as the computational time is huge. Thus we had to integrate a GPU for training, the implementation needed some extra research on the integration of a real GPU to train the model which was carried out by Camiel(Computer Science).

Based on the time we spent developing the initial training pipeline I believe that the practical approach I took was very successful as we managed to have the training script in a very early stage of the project (first month) so we could focus more on parameterization and evaluation.

In my opinion, there are both pros and cons when it comes to the freedom to do research at an individual level for a group project. First things first, more people means more extensive research thus less research time for the whole group thus faster implementation. On the other, the workload most of the time is not equally distributed so there are people who read more than others which introduces some level of unfairness within the team. Another reason that this approach might backfire is the fact that there is a great possibility that the teammates might waste a lot of time on something that is not really in alignment with the project requirements, an example from our group is the implementation of a database to store the different models and images generated, while this sounds really interesting and maybe crucial for the development of the end product, I feel like we spent a lot of time on that without being in the requirements.

All in all, I believe that the group members have to have enough freedom to do individual research as this is beneficial for the whole group, in the future, I would like to mitigate the risk of people sideling and maybe try to stop unnecessary research from happening as this is a waste of time and money.

3.2 Collect, Analyze, and Process information

3.2.1 Collect Information

Information Collection is a process that the researchers have to spend a lot of time on, in this phase of the research relevant information regarding the project is collected from various sources and with multiple ways. In our case, we conducted a literature review, interview, and experiments.

Literature Review: Conduct a comprehensive review of existing literature, including academic papers, books, articles, and relevant publications, to gain a thorough understanding of the research topic and identify existing gaps or areas of interest. For the literature review, we got a lot of help from our supervisor teacher,he provided us with some basic literature where we could use as a starting point for literature gathering.

1. Defect detection of MEMS based on data augmentation, WGAN-DIV-DC, and A yolov5 model[13]
2. Inspecting and classifying physical failures in MEMS during fabrication using computer vision [12]
3. A Gentle Introduction to CycleGAN for Image Translation[2]

Interviews: Conducting one-on-one or group interviews with individuals who possess relevant knowledge or experiences related to the research topic. For out project those individuals was Robert, who is our supervisor for this project with a background in computer science, as well as 2 interviews with Romas, the ex-student that worked on the original codebase for the image generation process. While Robert helped us a lot by providing literature and guidance throughout the process, the interviews we had with Romas really speed up our work. During the meetings with Romas we had a lot of questions regarding the software he created and the way that the defects are drawn on top of the mask image.

Experiments: One of the most challenging things we had to do is to understand how the image generation process works, so we can fine-tune the parameters to get a dataset with enough variance to cover all possible particle defects. To do that we experimented a lot with parameters focusing on one defect at a time, in our case the particles. The experiment focus on having most of the parameters fixed in a known value and then sweep through a specific parameter, that way we were able to evaluate the impact of the parameters in the image generation process.

3.2.2 Analyze information

In order to analyze the information a separation between literature review and developing is crucial.While literature review main focus is to synthesize existing research, identify gaps in knowledge, and provide a comprehensive overview of the current state of knowledge on a specific topic, analysis of the development phase has to do with the evaluation of the results

Literature Review

During the literature review we had to read past papers, documentation and generally gather the theoretical background in order to enter the developing phase.At this point i would like to mention that time wise literature review took place in many phases throuout te project. The idea is that in every run I had a goal in mind so I read only the corresponding literature, for example the first cycle was to create the training script there I had to focus only to the part regarding yolo training, another run was about the parameter optimization, in this phase I only researched about the parameter sweeps and different solution to deal with the wide range of parameters we had to take into account.

Analysis Developing phase

The Analysis during the development phase had mainly to do with the interpretation of our model results. With model results i mean the output labels, the output images, accuracy scores and training time. That part was crucial because we found a lot of bottlenecks in our models. During the analysis of the output images we had to identify issues with the prediction process, then try to figure out the reason for this problem and finally propose a solution in the data generation process to deal with it. There are 3 main issues that we faced during the analysis of the images.

a Over-fitting-Localization issues happens when a certain defect is detected as multiple smaller defects.The reason for this might be that the dataset has not enough variance so it can not identify a large shaped defects but it can identify small one with high accuracy. To mitigate the problem we decided to create sub-datasets for small medium and large size particle defects, that way we can make sure that different size defects are equally represented within the dataset.

b Locate particles that do not exists This issue troubled as the most and unfortunately i dont have a good explanation for this but a description, in very specific images, that we cannot see any actual differences, some parts are localized as particles while they do not exist.

c Identify letters as particles This issue had probably do with the fact that the mask we used to generate the artificial images had no letters while the original images had the logo of the manufacturer. As a result is some images letters are identified as defects. The solution proposed to mitigate the above issue was to redesign the mask so that includes the letters this time

(a) Overfitting

(b) No particle

(c) Letter as particles

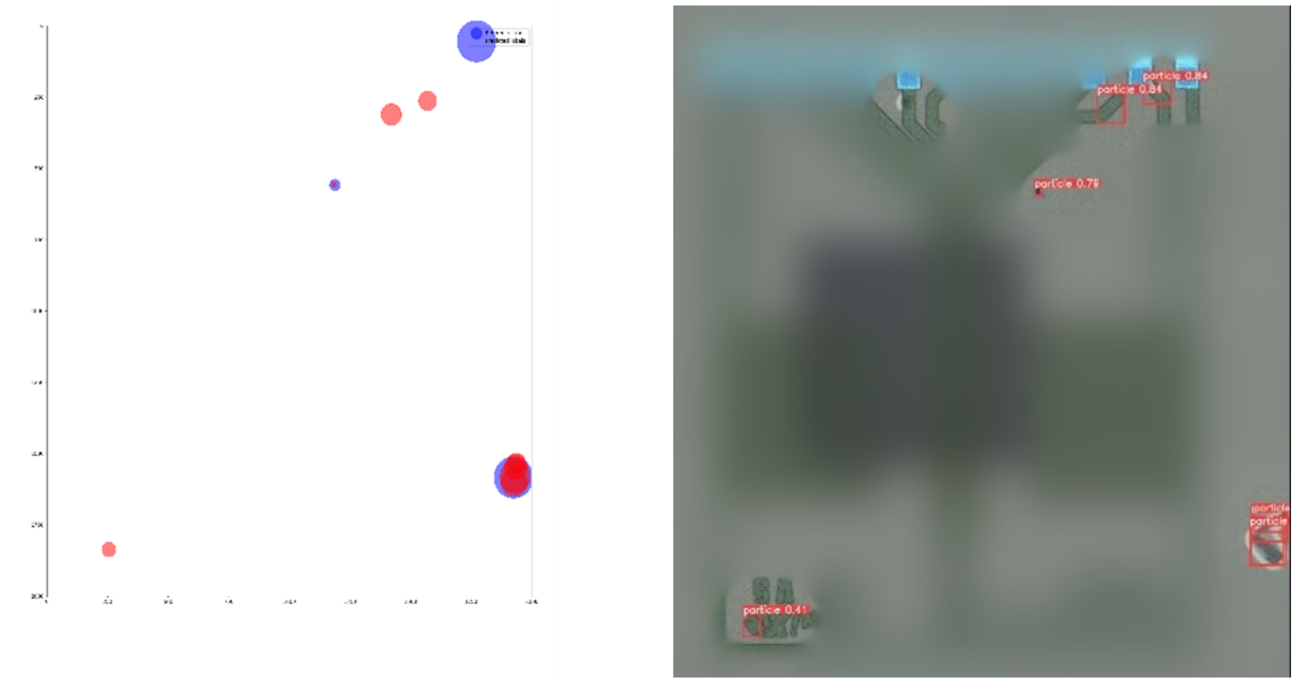
Figure 4: Image Analysis Issues

3.2.3 Process information

Information processing in my opinion is understanding the outputs of the model and trying to create ways to evaluate and compare different models. In order to evaluate the accuracy of different models we had to process the model outputs. In our case, we had to process 2 CSV files. The first file is the manually labeled dataset, this dataset is our goal. The second file is the YOLO-labeled dataset, this is the prediction file. Both CSV files have a similar structure regarding the feature names, to evaluate the localization ability of our model we need to focus on following variables for both datasets.:

- Width: The width of the bounding box
- Height: The height of the bounding box
- X: The x-coordinate of the bounding box
- Y: The y-coordinate of the bounding box

In order to visualize the effectiveness of our model, we first had to deal with the number of parameters we had to visualize, the problem is that there is no good visualization for 4 dimensions, thus we decide to bypass the problem by combining the Width and Height Variable to a new one called the area, now we only have 3 variables to plot. To give an extra layer of intuitiveness to our visualization we decided to create a bubble chart where the X and Y axis have the same size as the images, the bubble's center is the x and y coordinates for the labels, the radius of the bubbles is the same as the area of the square box and the 2 datasets are distinguished with color code red and blue as well as the opacity of 50%.



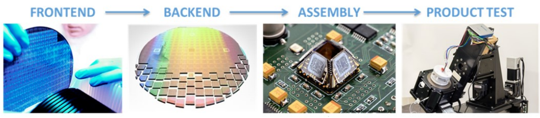
(a) Bubble Chart (b) Model Output

Figure 5: Model Evaluation

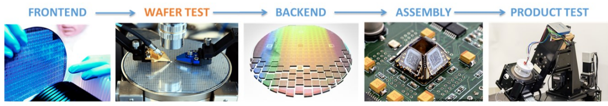
The script developed 1, gives us a nice way to visualize the effectiveness of our model. In future versions, spectrum analysis can give us a percentage linked to a specific model's effectiveness. Overall, the visualization approach and the bubble chart present an insightful and visually appealing way to assess and draw conclusions about our model's effectiveness in object detection tasks.

3.3 Working in an interdisciplinary project group; how did knowledge and skills of all disciplines contribute?

Inspection of MEMs devices on the wafer stage of the production chain is challenging and requires a lot of cooperation between different disciplines. This project by default is a multidisciplinary project as we need to combine hardware, software, and high-level physics models to get useful results when we try to predict the functionality of each specific module before unit testing.



(a) Typical Production Chain

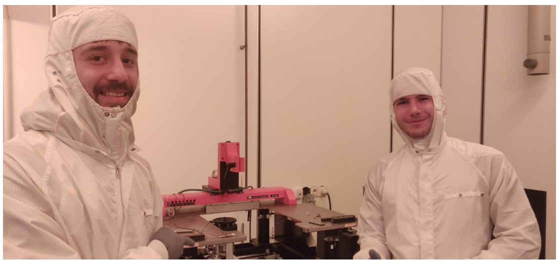


(b) Proposed Production Chain

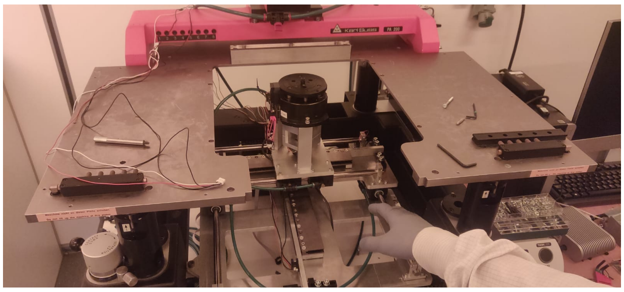
Figure 6: Project-Overview

3.3.1 Hardware

A camera that will visually inspect the devices on the wafer should be mounted on a camera setup that will parallel the wafer to the camera with a precision of 3mm. That is where our teammates from hardware engineering step up, after visiting the UT to see the machine we figure out that the wafer stabilization cart was missing, thus the team decided to start from there and redesign the probe cart as the previous design used ball joints where they do not offer high stabilization.



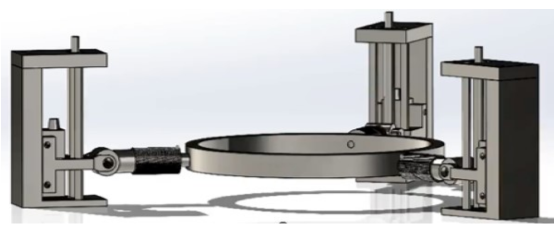
(a) Visit on UT clean room



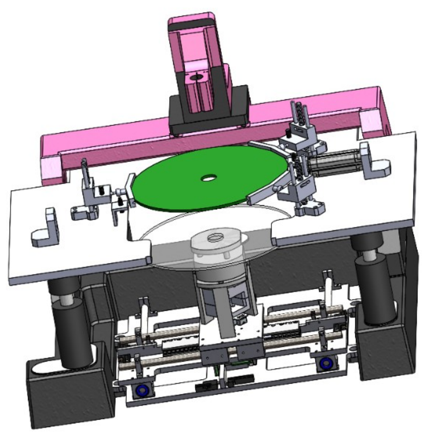
(b) Wafer Stabilization Cart Missing

Figure 7: Visit at the UT clean room

The new design incorporates linear encoders and stepper motors for improved accuracy and control. Linear encoders provide precise position feedback along a linear axis, enabling real-time monitoring and error correction. Stepper motors offer precise incremental steps of rotation, allowing for controlled movements and accurate positioning. This integration enhances the system's overall performance and makes it suitable for applications requiring high levels of precision and control.



(a) Stabilization Cart



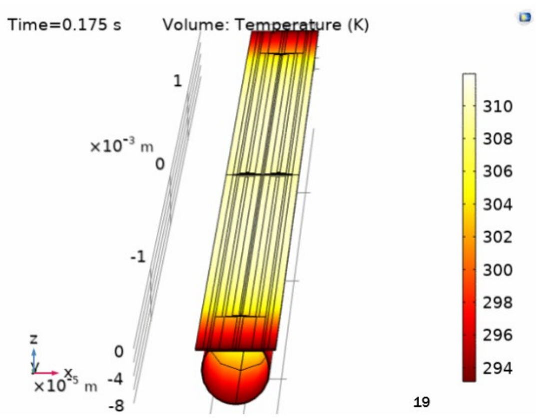
(b) SolidWorks Model

Figure 8: Design relization

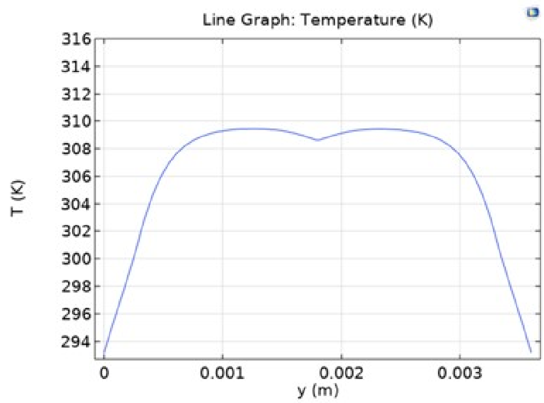
3.3.2 Physics Model

There is one more aspect to the project which is not been mentioned yet, the goal of the setup is to expand from a typical visual inspection to a thermal inspection as well, the idea is that probing techniques will heat up every individual module, afterward based on the thermal profile of the image, defects are going to be localized based on the swift of the heating curve.

To do that Martjin developed a COMSOL model. COMSOL is a multiphysics simulation physics tool that can be combined with 3d models and accurately simulate physics phenomena such as AC, DC heating, and flow.



(a) Comsol Model



(b) Heating Graph

Figure 9: Comsol Model

In the COMSOL model, defects are expected to induce fluctuations that can appear either on the right or left side of the graph. These fluctuations arise due to the disrupted flow or distribution of physical quantities, such as temperature or pressure, caused by the presence of defects

Figure 10: UI of synthetic Generation Tool

Listing 1: Bubble Chart Code

```python
## Draws a bubble chart for labels for an image
def plot_bubble_chart(labels_for_images: list[label_for_image]):
    image_shape = (1920, 2109) # extracted from yolo/test/0.png

    if not pathlib.Path('evaluation_plots').exists():
        os.mkdir('evaluation_plots')

    def plot_single_label_for_image(instance: label_for_image):
        reference_labels = instance.reference_labels
        prediction_labels = instance.prediction_labels

        # Plotting the results
        plt.figure(figsize=(19, 21))
        plt.xlim(0, image_shape[0])
        plt.ylim(0, image_shape[1])
        plt.gca().invert_yaxis()

        for label in reference_labels:
            x_center, y_center, width, height = label[1:]

            # Convert normalized coordinates to absolute coordinates
            x_center_abs = x_center * image_shape[0]
            y_center_abs = y_center * image_shape[1]

            # Convert width to size of bubble
            size = width * height * pow(10, 6)

            # Draw point
            plt.scatter(x_center_abs, y_center_abs, size, marker='o', color='
                blue', alpha=0.5)

        for label in prediction_labels:
            x_center, y_center, width, height, _ = label[1:]

            # Convert normalized coordinates to absolute coordinates
            x_center_abs = x_center * image_shape[0]
            y_center_abs = y_center * image_shape[1]

            # Convert width to size of bubble
            size = width * height * pow(10, 6)

            # Draw point
            plt.scatter(x_center_abs, y_center_abs, size, marker='o', color='red
                ', alpha=0.5)

        plt.legend(['reference', 'prediction'])
        plt.grid(True)

        # Remove extension from file name
        image_filename = "".join(instance.image_name.split('.')[:-1])

        # TODO: Backup previous plot before overwriting?

        plt.savefig(f"evaluation_plots/{image_filename}_bubble_chart.png", dpi
            =200)
        plt.close()

    if type(labels_for_images) == list:
        for instance in labels_for_images:
```

```
            plot_single_label_for_image(instance)
    else:
        plot_single_label_for_image(labels_for_images)
```

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