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International Master of Science on Cyber Physical Systems "MS@CPS"

30.05.2022

INTERNATIONAL MASTER OF SCIENCE ON CYBER PHYSICAL SYSTEMS

IN THIS ISSUE

Master of Cyber Physical Systems

MS@CPS

The International Master of Science on Cyber-Physical Systems (MS@CPS) provides a specialized and unified view of the industry-oriented research field, aiming to prepare the students to be highly skilled analyzer, designers, and developers of both the software and hardware aspects for various industry-related systems and applications in the context of CPS.

By enrolling in this program, the students will interact with people from several distinct countries, with diverse cultural backgrounds to promote globalization and technological development based on students' choices and expectations.

The ERAMSUS PLUS Key Action 2 (capacity building in higher education) has funded the work reported herein; project reference number: 598750 - EPP-1-2018-1-DE-EPPKA2-CBHE-JP, which is gratefully acknowledged.

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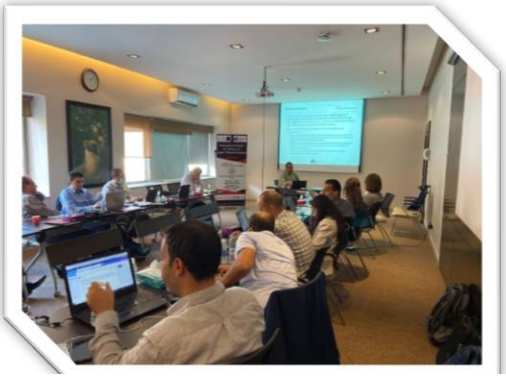


PROJECT INFORMATION

Number:
598750 - EPP-1-2018-1-DE-EPPKA2-CBHE-JP

Key Action:
Cooperation for innovation and the exchange of good practices – Capacity Building in the field of Higher Education

Consortium

Institutions of the program countries include the University of Siegen in Germany, the leader of program.

University of Hertfordshire in the UK, and the KTH Royal Institute of Technology in Sweden. Institutions from the partner countries include the German Jordan University and Tafila Technical University from Jordan, Carthage University and the University of Sfax from Tunisia, as well as Al-Quds University and Palestine Technical College - Deir El-Balah from Palestine.

F2F & ZOOM MEETINGS

On the third day, 28.1.2021, of the f2f meeting of the MS@CPS project consortium organized by Tafila Technical University (TTU) at Jordan: several presentations from the partners of the project were given. Firstly, Dr. Tarek Zlitni from the University of Safx (USF) presented his experience on the "Machine learning" course, and secondly, Dr. Rim Jallouli from the University of Sfax presented the experience of teaching the "Algorithms" course. Thirdly, Dr. Bchira Ben Mabrouk from Carthage University (UC) presented her teaching experience in the "Optimization" course. Then, Dr. Ala' Khalifah from German Jordanian University (GJU) resented about the experience in teaching the "Cloud Computing" course followed by Dr. Ammar Gharaibeh from German Jordanian University who presented about "Network optimization" and "Mobile communications networks" courses. Then, Dr. Ezzaldeen Edwan from Palestine Technical College (PTC) presented his experience in teaching the "Internet of things (IoT)" course. Finally, Dr. Hamidreza Ahmadian and Dr. Christian Weber from the University of Siegen Wrapped up the meeting and next steps to be done.

On the second day, 27.1.2021, of the f2f meeting of the MS@CPS project consortium organized by Tafila Technical University at Jordan several presentations from the partners of the project were given. Firstly, Dr. Ala' Khalifah from a German Jordanian university presented about progress in "WP4, Quality" and secondly, Dr. Christian Weber from the University of Siegen presented about the preparation of CPS curriculum and student books. Thirdly, Dr. Hamidreza Ahmadian from the University of Siegen presented about the management of the remaining deliverables of the project. Then, Dr. Ezzaldeen Edwan from Palestine Technical College presented about WP5, Dissemination, and exploitation. Dr. Rashid Jayousi from Al-Quds University presented his experience of the "Data analytics and data mining" course. Finally, Dr. Khalid Alemerien from Tafila Technical University presented his experience of the "Security and Privacy of CPS systems" course.

The first day of the f2f meeting of the MS@CPS project consortium organized by Tafila Technical University at Jordan, Tuesday 26.10.2021, was held with the participation of all partners of the project. The meeting agenda lasted all full day and included presentations from the partners of the project. Firstly, Dr. Hamidreza Ahmadian from USI presented about "Status of the project" and secondly, Dr. Christian Weber presented about development wok package. Thirdly, Dr. Mohamed Saleh presented about KTH experience in developing the entrepreneurship course.

WORKSHOPS

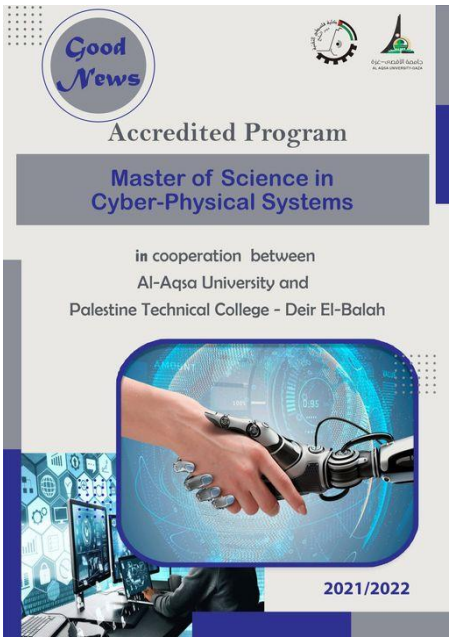
On the 26th of August 2021, the MS@CPS team at the higher Institute of Computer Science and Multimedia (ISIMS), University of Sfax held a meeting that was participated by Rym Jallouli, Tarak Zlitni, Faiez Gargouri, Walid Mahdi and Bassem Bouaziz. The team discussed the evaluation of the 2020-2021 academic year for the master and the preparation of the 2021-2022.

EVENTS

As part of its activities to promote and evaluate Erasmus + projects, the National Erasmus + Tunisia office organized a seminar titled: "Erasmus + 2015-2020: Impact of CBHE projects in Tunisia" on January 11, 2022, at the City of Sciences in Tunis in the presence of the Minister of Higher Education and Scientific Research of Tunisia and the Ambassador of the European Union in Tunisia. The Erasmus + MS@CPS project was represented by the University of Carthage team: Dr. Bchira ben Mabrouk, Dr. Haykel Ben Frej, and Dr. Walid Barhoumi

NEWS

On September 7, NEO Palestine Director Dr. Nedal Jayousi field visit the Palestine Technical College - Deir El Balah in a series of visits for Gaza Higher institutions, Dr. Jayousi was warmly greeted by the Rector of PTC dean Dr. Haitham Ayesh. Dr. Haitham Ayesh expressed that it is a great pleasure to have Dr. Jayousi at PTC, stressing that Erasmus+ projects are distinguished and add tremendous value to higher education. After the opening of a session,



Dr. Nedal Jayousi announcing that the upcoming call for Erasmus+ projects will be open at the end of October 2021. Dr. Jayousi pointed out that the overall project budget will increase this year. Dr. Jayousi also provided brief instructions on proposal writing and submitting procedures, encouraging the college to participate actively in the new call and he promised to support PTC in this field. Firstly, Mr. Ahmed Agha introduced a brief history of PTC and statics that show the number of projects. Following the information session, CBHE projects coordinators had the floor to conduct presentations regarding the progress and outcomes of various projects. Dr Ezzaldeen Edwan, the Director of the CBHE project: "Edu4All," talked about the main accomplishments of the program. Dr. Marwan Jalmbo, the Director of the ECNAD project, conducted a brief presentation on the progress of the project. Dr. Ezzaldeen Edwan, the Director of the "International Master of Science on Cyber-Physical Systems" project, provided a brief introduction and progress of the project, then talked about the cooperation with AL- AQSA university in the teaching master program. At the end of the visit, Dr. Nedal Jayousi be surprised with the readiness of the college for this visit and the level of progress for these projects inside the college.

On the 27th of December 2021, an MS@CPS project Advisory Monitoring meeting was conducted by the Tunisian national Erasmus+ Office for the University of Sfax. The meeting was attended by project coordinator: Siegen University and by the University of Carthage as well.

Clustering Wafer Defect Patterns within the Semiconductor Industry[1]

Introduction

Industry 4.0, cyber-physical systems (CPS) and internet of things (IOT) based concepts of smart production systems are nowadays dominating the discussion of a better, interconnected vision of manufacturing. Information and the ability of turning it actionable is becoming a core enabler of product-oriented companies, producing faster, with a stable and managed quality and increasingly shorter production cycles, blending high end manufacturing considerations with additional cross-disciplinary and complex requirements which emerged with the raising awareness of cyber-physical systems. This is especially true for the manufacturing of semiconductors. Knowing and planning the yield of manufacturing within the semiconductor industry is highly important, yet the increasing complexity of manufacturing processes is rendering it hard to do a forecasting or a root cause analysis.

According to studies human-expert based defect pattern recognition methods have a maximum accuracy of about 45%. To help engineers to improve recognition and root cause analysis of defect patters and therefore increase and stabilize the yield, we introduce a novel analysis process for finding unknown defect patterns, using an unsupervised machine learning technique for an integrated clustering process. The unique contribution is the composition of well-known algorithms into a flexible tool to on demand support the root-cause analysis of analytical experts. The data-driven process is a valuable role model for how a data-infrastructure and a pipeline of smart algorithms do enable rapid but sustainable solutions to handle unknown situations in complex manufacturing environments.

Wafer Maps

A semiconductor is a product made from a solid chemical compound, that can conduct electricity in certain conditions but not under other conditions, making it a medium for electrical current control. To produce microchips, circuits are manufactured on top of a large, round slice or tray of silicon, called the wafer. The wafer can carry multiple chips, called dies in a grid on top of its surface and is the target of a multitude of processes in the production which are building the final microchip structures in layers [2].

A wafer map is a virtual representation of a wafer, describing the locations of dies on the physical wafer. Binning is the mechanism whereby each unit on the wafer is given bin code, representing the state of dies. As such they are a direct data transformation of the collected states and can be utilized to track patterns of defects across large populations of wafer. However, such patterns, in large quantities, may not be distinct enough for human experts to group them in significant clusters for a defect analysis.

A Smart Approach for Clustering Wafer Defect Patterns Based on Wafer Maps

The focus of this work is on developing an unsupervised clustering solution to support engineers in the pre-grouping of wafers with defects. Enabling thus to recognize patterns and group those patterns into unique clusters. These clusters are then in a second step used by engineers to do a root-cause analysis based on the discovered groups. However, the engineer has to be able to rate the validity of the groupings to be able to select clusters which are promising for analysis. Therefore, this work is divided into two parts. The first task is to select a sequence of algorithms that returns the accurate clusters for the unlabeled wafer map data and the second task is to use a classification algorithm to train and classify the clusters to evaluate the detected defect patterns based on the cluster membership and the available wafer maps. The intended composition and process flow of the solution is shown in Figure 1.

[1] This article is a summary of the published article [1]: C. Weber, A. Tripuramallu, P. Czerner, and M. Fathi, 'Clustering Wafer Defect Patterns Within the Semiconductor Industry Based on Wafer Maps, Using an Agile Unsupervised Deep Learning Approach', in 2021 IEEE International Conference on Systems, Man, and Cybernetics (SMC), Oct. 2021, pp. 1913–1918. doi: 10.1109/SMC52423.2021.9658907

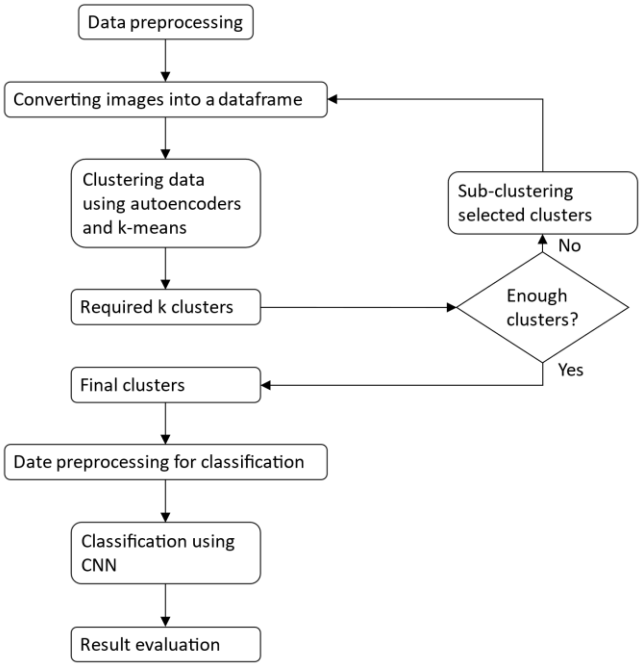
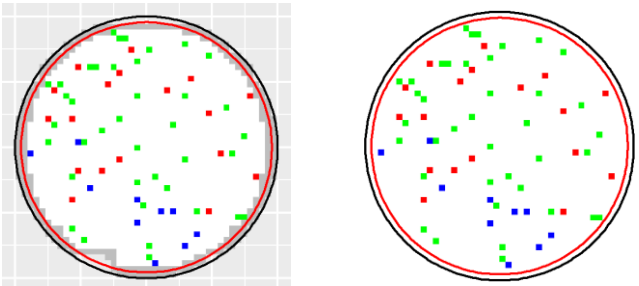


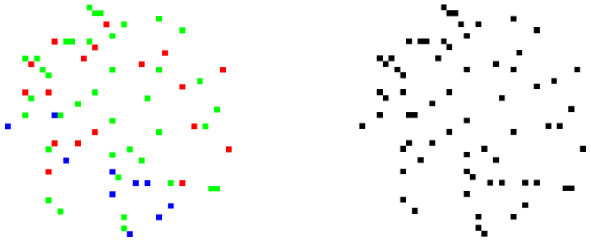
Figure 1. Flowchart of the solution composition.

Wafer Map Data

To evaluate the proposed solution, a data set of wafer maps is generated and tested in collaboration with the Elmos Semiconductor SE. Figure 2 visualizes the sequence of pre-processing steps on an example wafer, leading to the final input images.



a) Original b) Grid removed



c) Outer rings removed d) Colors removed

Figure 2. Visual data cleaning of the target images (a-d)

The outer circles denote the physical boundary of the wafer and the internal boundary within which dies cannot be fully processed as they are partially outside of the physical edge of the wafer. The grey background area is intended to help to visually localize dies on the wafer. However, for the clustering and the later classification, these areas do offer no variance and therefore no information. Hence, the data is preprocessed, and the images are cleaned to retain only the essential information.

Wafer Map Clustering

Multiple clustering methods were tested, each with different shortcomings. K-means clustering [3] showed stable results throughout variations of the data set and were selected. To utilize k-means, the appropriate number of clusters has to be defined. For this he elbow method [4] is used to derive the likely number of clusters for k-means.

Reducing the Feature Space with Autoencoders

K-means works with distance matrices and tend to be less accurate when it comes to high dimensional input data such as images. To avoid the problem, the k-means algorithm is combined with an autoencoder to reduce dimensionality and use the data cleaning effect of the autoencoder's generalization. The autoencoder [5] is implemented, using a fully connected symmetric autoencoder model with seven layers. By training the autoencoder, the encoder compresses each image from 5481 features to 64 features. A custom cluster layer is used for converting the input features into cluster label probabilities. The clustering model is formed by stacking this custom clustering layer after the trained autoencoder.

Classification and Evaluation

A classification algorithm is added to enable a training/validation-based evaluation of the likely validity of the created clusters. The intuition is that a successful prediction of the clusters, indicates a sufficiently isolated data trend within the clusters to enable a cluster-based prediction, thus approving the clustering results. A deep convolutional neural network classifier is created for this with a base Keras implementation.

Results

The use-case for the system evaluation consists of 3,950 color semiconductor wafer map images with a size of 590*590 pixels. The images belong to 158 lots, consisting of 25 wafer maps each. The data set corresponds to a manufacturing problem, where a single machine processed for each lot of wafers a single wafer with a limited quality, leading to patterns of defect chips. Using the elbow curve for the given data set a value for k of 10 clusters is selected for the clustering.

In the resulting clusters, groups are showing similar patterns. This trend is shared across all 10 clusters. Considering the use-case, indeed the defined system was able to collect the majority of cases which reflect the malfunction of the known single machine are collected in one single cluster. Cluster 3 includes with 66.5% the highest concentration of wafers of the targeted source of defects, collecting 105 of the 158 affected wafers. For all remaining clusters, a human expert was able to attach a verbal label, underling the successful clustering.

Resulting, the clusters can be sufficiently predicted by the neuronal network with sufficient accuracy for a significant prediction. Therefore, for the given use case of a known root-cause for specific defect patterns, the hybrid clustering solution is able to derive meaningful patterns and isolate the known main root cause for wafer defects. Capturing the majority of wafers of the known root-cause into one cluster could shows the ability to identify unknown, yet significant patterns for a root cause analysis to support a human expert for the task of root-cause analysis. This enables to rapidly narrow down the potential sources for a specific error. Combined with the option to allow experts to further cluster generated clusters, the engineer gains a valuable tool for a guided, agile root-cause analysis. The in deep description and analysis can be read in the published full paper [1].

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AUTHORS

Dr. Christian Weber, He is a researcher with the Institute of Knowledge-Based Systems and Knowledge Management (KBS & KM), University of Siegen, Germany. He is continuously researching on the exploitation of evolving knowledge maps for an ongoing industrial, educational and medical digitalization using AI and is active for that in national and international funded research projects (DFG, BMBF, H2020, Erasmus plus and many more) but also direct industrial collaborations. He believes that any digital solution has to have a human factor and so does academia. He received a Marie Curie early researcher scholarship as part of the Eduworks doctoral network and received his PhD from the Corvinus University, Budapest. Within his PhD he was working on developing semantic and structure-aware concept importance measures for domain knowledge to guide digital learning.

Prof. Dr.-Ing. Madjid Fathi, He is the Chair of Institute of Knowledge Based Systems (KBS). Prof. Fathi received his M.Sc. in informatics and Ph.D. in mechanical engineering, both from the University of Dortmund. He obtained his Habilitation degree in informatics and automation from the University of Ilmenau. Prof. Fathi served as a Visiting Scholar at the University of New Mexico, Florida State University and later LMM at the Georgia Institute of Technology, USA. He was a Visiting Scholar at the U.C. Berkeley with Prof. Zadeh (the Father of Fuzzy Logic) between September 2012-2013. He has supervised, coordinated and contributed in several Research and Development projects funded by EC, German Research Foundation (DFG), and Federal Ministry of Education and Research (BMBF) as well as industrial projects in cooperation with neurosurgery clinics. His research interests are focused on Knowledge Management applications in Medicine and Engineering, Computational Intelligence and Knowledge Discovery from Text (KDT). Prof. Fathi is the editor of severa textbooks and peer reviewed journals in the aforementioned areas.

Project Leader

The consortium is led by the University of Siegen in Germany. The University of Siegen has a long running experience of combining embedded systems, as the overarching concept for CPS, knowledge management and intelligent systems, to continuously utilize the intersection for research and teaching throughout the master's degree domains of computer science and electrical engineering. In consideration of the implemented best practices at the University of Siegen, a jointly developed pedagogy is in focus of the MS@CPS master program.

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