IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.53

Volume 4, Issue 2, July 2024

Design and Development of AI based Wiring Harness Simulator for Pigtail Wiring Harness Development in Electrical Checkout System (ECOS)

Jeganath Y P[1], Dr. Arvind A R[2], Harivignesh G[3]

Pre-Final Year Student, Madras Institute of Technology, Chennai[1]

Deputy General Manager, Ashok Leyland, Chennai[2]

Assistant Manager, Ashok Leyland, Chennai[3]

Abstract: *Electrical Checkout System (ECOS) tool validates electrical loads by quantifying their resistance in a typical production line of a commercial vehicle manufacturing organization. Model specific pigtails needs development for connecting the ECOS equipment with commercial vehicles in production. Conventional manual approach is used for Pigtail ECOS harness design and development which is both time-consuming and prone for errors. This project is related to the accelerated design and development of pigtail ECOS harness utilizing the power of Artificial Intelligence in analyzing the input wiring diagrams spanning multiple sheets in PDF format and accurately identify the wire loads. The AI provides the result in the form of tabulated spreadsheets consisting the data of wiring loads and pin details. Through this project the lead time for harness design and development is reduced significantly.*

Keywords: ECOS, Wiring Harness in Automobiles, Artificial Intelligence, Industry 4.0, Robotic Process Automation, Computer Vision, OpenCV, Tabula, Pandas

I. INTRODUCTION

A wiring harness is an essential element of automotive systems, comprising an organized set of wires, cables, connectors, and terminals that transmit electrical power and information throughout the vehicle. It simplifies the assembly and manufacturing process by consolidating several wires into a single, well-organized unit, which reduces complexity and makes it easier to monitor and troubleshoot. The wire harness improves the overall safety and efficiency of modern automobiles by ensuring that electrical connections are structured and secure.

A pigtail harness refers to a short length wiring harness used for testing and miscellaneous applications. This system simplifies and standardizes electrical connections, making installation and replacement of components more straightforward. The design of a pigtail harness system entails complex duties such as determining the path of wires, placing connectors, pin configuration, ensuring signal (load) quality, and considering ease of manufacturing. The ECOS tool verifies electrical loads by measuring their resistance. A precision Analog Digital Convertor (ADC) measures the voltage across the load, and the ECOS calculates the load's resistance. This process ensures that the wiring is intact and the load is properly connected. If the measured resistance is within the expected range, the load is confirmed. After the loads are confirmed pigtail harness diagrams are generated with pin details at the design stage.

Conventional design procedures can be characterized by their time-consuming nature, heavy reliance on human labor, and susceptibility to errors. Creating a specialized software solution that automates and optimizes several areas of pigtail harness design has the potential to greatly decrease the time needed for design revisions and improve overall design effectiveness. This project is focused on the rapid design and development of pigtail harnesses systems in a commercial vehicle manufacturing industry.

Industry 4.0, heralded as the Fourth Industrial Revolution, is transforming traditional manufacturing through the integration of advanced technologies like artificial intelligence (AI), the Internet of Things (IoT), big data analytics, and automation. This paradigm shift towards smart factories and digitalization enhances productivity, efficiency, and flexibility in production processes. Cyber-physical systems and interconnected devices enable real-time data exchange, predictive maintenance, and decentralized decision-making, fostering a more responsive and adaptive manufacturing

DOI: 10.48175/IJARSCT-19243

environment. The adoption of Industry 4.0 is progressing rapidly as businesses seek to gain competitive advantages through innovation and efficiency improvements.

In this context, the wiring harness project exemplifies the principles of Industry 4.0 by leveraging Robotic Process Automation (RPA) and AI to revolutionize the design and development process. Traditionally, wiring harness design is a labor-intensive task prone to human error, requiring meticulous analysis and documentation. By employing RPA, the project automates the analysis of input designs and accurately identifies wire loads, significantly reducing the time and errors associated with manual efforts. Additionally, RPA facilitates the interconnection of wires across numerous PDF documents, ensuring consistency and efficiency. This not only streamlines the design process but also enhances the accuracy and reliability of the final product. The integration of AI for design analysis further exemplifies the smart algorithms central to Industry 4.0, enabling data-driven decision-making and continuous improvement.

II. REVIEW OF LITERATURE

Current wiring harness design workflows often involve fragmented data scattered across multiple file formats, including electrical schematics, 3D CAD models, and cable lists. This leads to significant challenges for both production and electrical teams:

Production teams: Difficulty in accurately tracing wire paths and identifying potential bottlenecks during manufacturing, leading to errors and inefficiencies.

Electrical teams: Time-consuming manual effort required to consolidate data from different files and validate harness designs, delaying development and troubleshooting processes.

Existing software solutions for harness design tend to focus on specific aspects like routing optimization, collision avoidance, or cost estimation. While these tools offer valuable assistance, they do not address the critical need for holistic integration of internal wire route data from multiple file formats.

Previous Papers and Their Solutions:

Castorani et al. [5] presents a valuable method for optimizing cable tray layout and routing to reduce costs in industrial settings. However, while this approach is beneficial for cost considerations, it focuses on a specific aspect and doesn't address the broader challenge of integrating and classifying data from various file formats commonly used in industrial design projects.

Pradhan [4] emphasizes the importance of optimizing various aspects of harness design, such as cost, weight, and functionality. He highlights the value of advanced tools for achieving this optimization. However, he does not delve into the challenge of fragmented data, which can be a significant hurdle in the design process. Fragmented data, existing in different formats across various sources, can hinder efficient design optimization.

Pemarathne et al. [1] delves us into various AI techniques employed, such as genetic algorithms, neural networks, and fuzzy logic, highlighting their potential benefits for optimizing harness design. However, the authors acknowledge that challenges persist, including the substantial data requirements for effective AI implementation and the need for robust methods to evaluate AI performance in this context. These challenges present opportunities for further research.

J. Silva et al. [6] approach integrates data from various sources, including schematics, CAD models, and cable lists. By leveraging machine learning for analysis, the study demonstrates a significant 15% cost reduction in a real-world case study. While the paper showcases the power of data analytics, it does not explicitly address the challenge of creating cable lists from the outset. In practice, fragmented data sources often necessitate this initial step, and future research could explore methods to automate or streamline cable list generation from diverse data formats.

Karlsson et al. [7] present a methodology for automating cable harness routing within a user-defined 3D environment. This approach allows for incorporating design rules and constraints, such as collision avoidance and preferred routing zones. By doing so, the method ensures that the generated cable harness layouts adhere to specific design requirements. It's important to note that the paper focuses on the routing process itself, and doesn't delve into the topic of acquiring the initial wiring harness data information.

Conru AB et al. [8] describes a system for interactive cable harness routing and design offering significant advancements in automation of the routing process within complex, three-dimensional environments. It allows designers to intervene and modify the computational results at any stage, providing a balance between automation and manual input but it does not detail how to integrate diverse data sources to form this initial configuration

Han N et al. [18] introduces a novel method for cable harness routing that prioritizes the main channel path, employing a top-down design strategy, parts spatial distribution, and specific path definition rules. The paper also presents an optimized cable harness path algorithm based on undirected-graphs. However, the challenging task of obtaining organized data from fragmented data remains unattended.

Gao P et al. [17] identifies manual labor as a bottleneck in aircraft development due to the predominantly handcrafted manufacturing of aircraft harnesses. To enhance production efficiency, the study analyzes the characteristics of aircraft harness production processes and proposes a production process model using network graphs to calculate standard cycle times. However the challenge of acquiring structured data from fragmented data is not addressed.

Kobayashi et al. [13] emphasizes the need to optimize assembly processes of wire harnesses efficiently without relying solely on CAD/CAM-based systems. Despite their use, engineers still face challenges in finding optimal assembly processes, often resorting to trial and error. The paper proposes a new method focusing on optimizing the taping process—a critical and challenging step in wire harness assembly—by modeling and optimizing the layout of jigs and taping routes using a genetic algorithm.

Ng FM et al. [14] underscores the critical challenges in cable harness design and planning, noting their essential yet often overlooked role in electromechanical systems. The paper reviews existing literature and draws insights from a case study involving advanced manufacturing organizations to validate current industrial practices. It identifies cable harness design as a sequential and iterative process typically performed late in the product development cycle, with minimal integration across core activities.

Park H et al. [15] discusses the imperative of developing a structured framework for concurrent design support in industrial cable harness design, addressing challenges that hinder the adoption of efficient design practices. The paper emphasizes the development of an architecture that facilitates collaboration among specialists and the creation of hierarchical representations to capture diverse design characteristics.

Moore S et al. [16] highlights the deficiencies in traditional wire harness costing methods, which often overlook complexity-related costs stemming from variations in part counts. These costs, frequently underestimated or simplified, can significantly impact organizational expenses and complicate efforts to optimize design and production. The paper specifically addresses the challenges involved in the initial cable layout design and the integration of fragmented data sources.

Kamm et al. [9] emphasize that in industrial automation, integrating and analyzing heterogeneous data is crucial. Artificial Intelligence is favored for its ability to uncover complex correlations across diverse data sources such as sensors and logs. This paper aims at providing using AI for automating wiring harness design.

Trommnau et al. [10] emphasizes the urgent need for automation in automotive wire harness manufacturing due to factors like component miniaturization and increased process documentation demands. However, the paper does not address specific challenges such as integrating AI for real-time quality control or optimizing human-machine interaction.

Masoudi N et al. [11] highlights the criticality of optimizing connector layouts to minimize weight and maximize efficiency in complex systems like automobiles and ships. He underscores the potential of advanced tools in achieving these goals. However, Smith does not address the challenge of drafting the connector layout design, which can significantly impede the optimization process. Fragmented data, dispersed across different formats and sources, poses a substantial hurdle to efficient connector layout design.

Saekyeol Kim et al. [12] highlights the necessity of developing a systematic framework for routing layout design in commercial trucks, addressing challenges that hinder the adoption of existing routing algorithms by automotive industry designers. While focusing on optimizing the routing of tubes, hoses, and cable harnesses, Kim emphasizes the practical implementation of a sequential graph-based routing algorithm for efficient operations. However, Kim does not explore the integration of fragmented data sources, which remains a critical obstacle in achieving comprehensive routing optimization.

Zozaya et al. [23] focuses on the intricate process of designing automotive electrical wire harnesses, which must navigate numerous physical, electrical, thermal, and mechanical constraints. The harness topology needs to align

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 2, July 2024

precisely with the vehicle's physical configuration. Additionally, the harness must ensure adequate current transmission and voltage supply to all electrical devices, performing reliably even under demanding conditions. However, Zozaya does not address the critical need for initial wire routing, which is often determined through a trial-and-error method. This initial routing is essential for optimizing harness design but remains a gap in current methodologies. Integrating a systematic approach to initial wire routing could significantly enhance the efficiency and effectiveness of the design process.

Ioana et al. [24] emphasizes the growing importance of wiring harness production due to the increasing need for improved security and multimedia systems in the automotive industry. The integration of new technologies presents a significant challenge for wiring harness manufacturers, who still rely heavily on human resources.

Wei [25] highlights the considerable complexity generated by the large number of vehicle wiring harness variants during the design phase, which needs effective management at the production level. Typically, wiring harness design optimization focuses on minimizing product costs without considering issues related to manufacturing processes. However, while Wei addresses the overall complexity and cost optimization, the critical need for initial wire routing - often determined through trial and error - the integration of fragmented data from various sources are not sufficiently addressed. These aspects are essential for optimizing harness design and production efficiency, presenting a significant gap in current methodologies.

Marie et al. [26] addresses the challenge faced by car manufacturers of designing a large variety of electrical wire harnesses due to increasing competition and high customer expectations. The work emphasizes the use of component commonality to help reduce the number of different wire harnesses needed. The study introduces greedy heuristics, a descent method, and a variable neighborhood search meta-heuristic to provide high-quality solutions in a reasonable computing time. While Marie focuses on cost savings and solution methods, the critical need for an efficient initial wire routing, often determined through trial and error, and the integration of fragmented data sources are not adequately addressed.

These, therefore present suitable venue for improvement and enhancement using AI for automating the design and development process to the extent of reducing manual human interventions to a large extent.

III. WORKFLOW

The basic work flow of the project so as to meet the objectives,evolves on the following :

Extracting Data from portable documents (*.pdf)

Analyzing the Data from the extractedportable documents (*.pdf)

We now examine each process in the main workflow in depth, while ensuring that the overall workflow remains as straightforward as possible.

3.1 Extracting Data from the PDF’s

The PDF contains numerous tables and diagrams accompanied by descriptions. The goal is to retrieve the Connector tables and master tables. The connector tables comprise ‘x’ columns and feature the connector name as the header. The master table lacks a title and contains ‘y’ columns. The resulting output will be a dictionary where the title serves as the key and the table's data frame serves as the corresponding value.

3.1.1 Read the PDF Files

The PyMuPDF library, an open-source Python library, is utilized to read PDF files. The rendering it provides is highly efficient and well-suited for the project. Additional libraries, such as PyPDF2, pdfplumber, ReportLab, and others, can also be utilized to open PDF files. Additionally, there are several libraries specifically designed to extract tabular data from PDFs, such as Camelot, Tabula, img2table, and others. These libraries function flawlessly, but they retrieve data from all tables within the specified table, which is unnecessary.

We simply need the tables containing the connectors and the master tables. Consequently, it is necessary for us to utilize our own filtering method and only access the required table.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 2, July 2024

3.1.2 Convert PDF to Images

The PDFs are converted to images for the purpose of facilitating image processing and extracting the specific areas of interest, namely the connector tables and master tables. It should be emphasized that the photographs have a good resolution. For this instance, the DPI has been configured to 300, which is an adequate resolution for image processing.

3.1.3 Find Tables

This step is the pivotal point in the process. The fundamental concept is to detect the outlines of the image and subsequently filter them. Contours in an image are the boundaries of objects or forms that have uniform intensity or color. Initially, we will extract all the contours.

In order to determine the contours, it is necessary to perform pre-processing on the image. Prior to further processing, it is necessary to convert it into a binary image. To isolate the vertical and horizontal lines, we employ erosion and dilation operations on the binary image using specific horizontal and vertical kernels. However, the presence of a significant number of lines in the texts is also noticed, which is undesirable. Therefore, a function is constructed to eliminate those lines that have a comparatively shorter length than the other lines.

Following the previous stage, the contours are retrieved from the binary image, which exclusively contains horizontal and vertical lines.

In order to extract the necessary tables, the following criterion has been employed.

MAX (Area of Parent Contour + Sum of Area of Child

Thus the contour of the Parent becomes the outline and the Child contours are the contours of the table. The coordinates of all the tables are stored.

3.1.4 Find Connector and Master Tables

Among the tables that were extracted, our goal is to identify the title of each table. The following logic, as explained in Fig 3.1.4.1, is applied to filter out the connector tables and master tables.

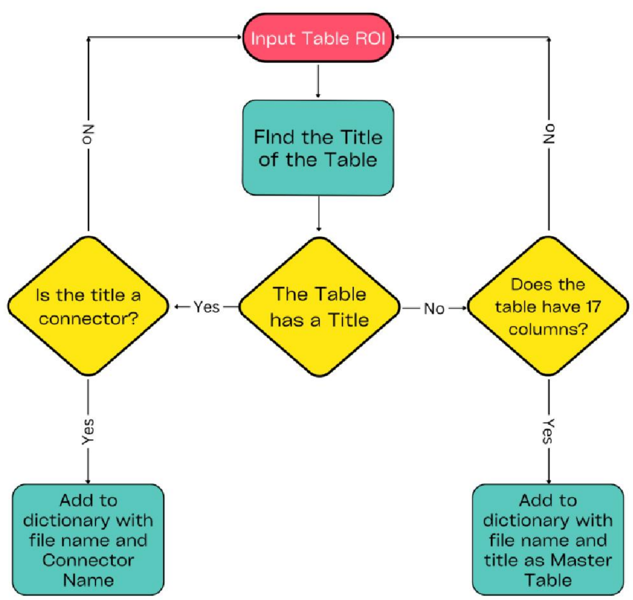


Fig 3.1.4.1

The connector is always denoted by a name that commences with the letters "IL" and concludes with the letter "P" which may be followed by certain numbers. Thus criteria to find the connector is a regex expression which is as follows

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 2, July 2024

"^IL.*P.*$"

To find the number of columns we can use the processed binary image which consists only the vertical and horizontal lines. The algorithm to find the number of columns is

Number of Vertical Lines inside the table Contour + 1

3.1.5 Read Tables

Once the necessary region of interest (ROI) has been isolated, data can be extracted from it. There are two alternatives available for reading tables in this context.

Converting the contours to PDF and reading from the PDF

Reading from the images of the PDF

Reading data from the PDF is advantageous because it is text-based, and the Tabula module in Python is well-suited for working with text-based PDFs. However, for PDF files that are image based, the second choice would be more desirable.

The tabula offers two distinct approaches for reading a table: Stream and Lattice. The Stream use whitespaces as a delimiter, while the Lattice employs lines as a delimiter. Ensure that the Lattice feature is activated for tables with borders, and the Stream feature is activated for tables without borders. Lattice option is used in this particular situation.

Upon transforming the Image coordinates into PDF coordinates, we proceed to extract and store all the tables. Each table is assigned a suitable title, which serves as the key in a dictionary. Each key would hold the data frame corresponding to the table. The key was selected based on the specified parameters.

PDF Name + " - " + Table Title

The string serves as the delimiter, enabling access to both the pdf name and the table name.

3.1.6 Convert to Microsoft Excel file

Converting the data frames stored in the dictionary to Excel is a simple process, where the name of the Excel file will correspond to the key of the data frame in the dictionary. It is necessary to carefully verify the saved excel files in order to prevent any problems in the subsequent phases.

3.2 Analyzing the Data from the extracted from the PDF's

During this step, our objective is to identify the quantities specified in the description for each connector table by establishing their connections with the master tables.

Upon extracting the tables from the PDF, it is essential to verify the accuracy of the contents and implement any required modifications to facilitate data accessibility. In current situation, the column labeled "Cav To." was modified to "Cav_To" and likewise the column labeled "Cav From." was altered to "Cav_From".

Once the necessary modifications have been made to the excel file, the data can be analyzed.

3.2.1 Reading Excel Files

In order to compile a list of all the available connectors, we must scan the directory that has the collection of Excel files that have been processed. A dictionary is utilized to hold the connector name as the key and its corresponding value, which is the data frame obtained from reading an excel file. A checkbox displaying all possible connectors is presented to allow the user to select the connectors for which reports should be generated.

3.2.2 Comparable Parameter Generation

Each connector is assigned a distinct name in a separate file, and they may have multiple variations and flavors. This complexity makes it challenging to identify them using a basic equality operator. In order to compare or locate the corresponding connector, it is necessary to carry out certain actions on the name of the connector.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 2, July 2024

In order to construct the similar, a straightforward split function, employing all the special characters as the split parameters is used. As a result, the special characters in the string are eliminated and the substrings are then returned as a list.

Now, let's examine several samples and the corresponding output they provide.

Connector Name: IL_FR_CHASSIS_TO_RR_CHASSIS_26P_0

Connector Name: IL FR CHASSIS TO RR CHASSIS_26P

Connector Comparable: ['IL', 'RR', 'CHASSIS', 'TO', 'FR', 'CHASSIS', '26P']

As shown, both connectors are identical, but they cannot be equated based solely on their raw strings. Therefore, we build a comparable list that can be used to equate the connectors.

3.2.3 Master Table Creation

A single PDF file has numerous distinct master tables that are segregated. In order to access all the values in a single data frame, we need to merge it. One way to accomplish this is by iterating through the files and merging the main tables of each file into a unified data frame. The quantity of master data frames must ultimately match the quantity of uploaded PDF files.

3.2.4 Main Loop

Following the earlier approach, we refer to the main loop. The main loop is where the entire analysis process occurs. Once the user selects the connector names, we proceed to individually examine each one and access their corresponding connector table. The description of each pin in this table can be accessed. Subsequently, we must locate the mate of the connector and determine the corresponding pin number in our comprehensive master databases. We can then proceed by applying the relevant idea. The concept for the main loop is simple and can be explained in the Figure 4.2.4.1.

```
For connector in file_list:
        final_dict={"Desc":["Pin"]}
        connector_df=find_connector_df(connector)
        master_df=find_mate_master_df(connector)
        forindex,rowinconnector_df.iterrows():
            desc=row["Wire #"]
            pin=row["Cav"]
            ifdesc=="-":
                continue
            l=load(connector,pin)
            nl=filter_list(l)
            final__list=remove_duplicates(nl)
            final_list=[pin]+final__list
            final_dict[desc]=final_list
```

IJARSCT

ISSN (Online) 2581-9429

IJARSCT

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.53

Volume 4, Issue 2, July 2024

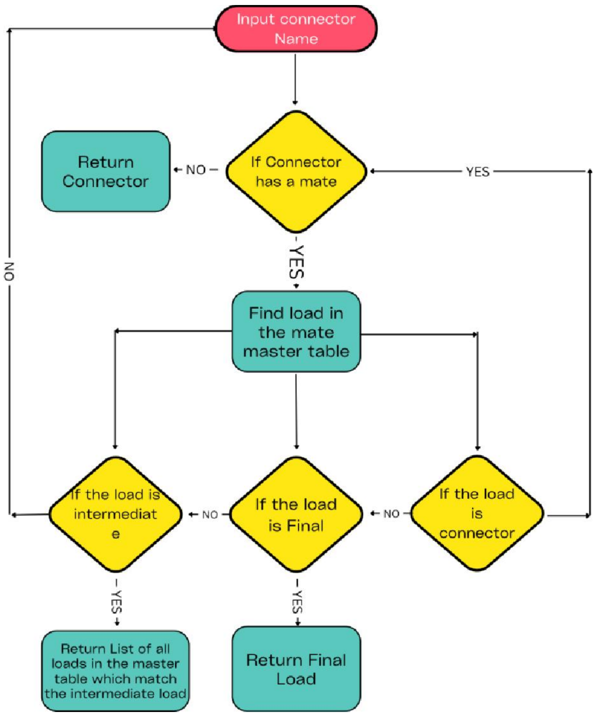
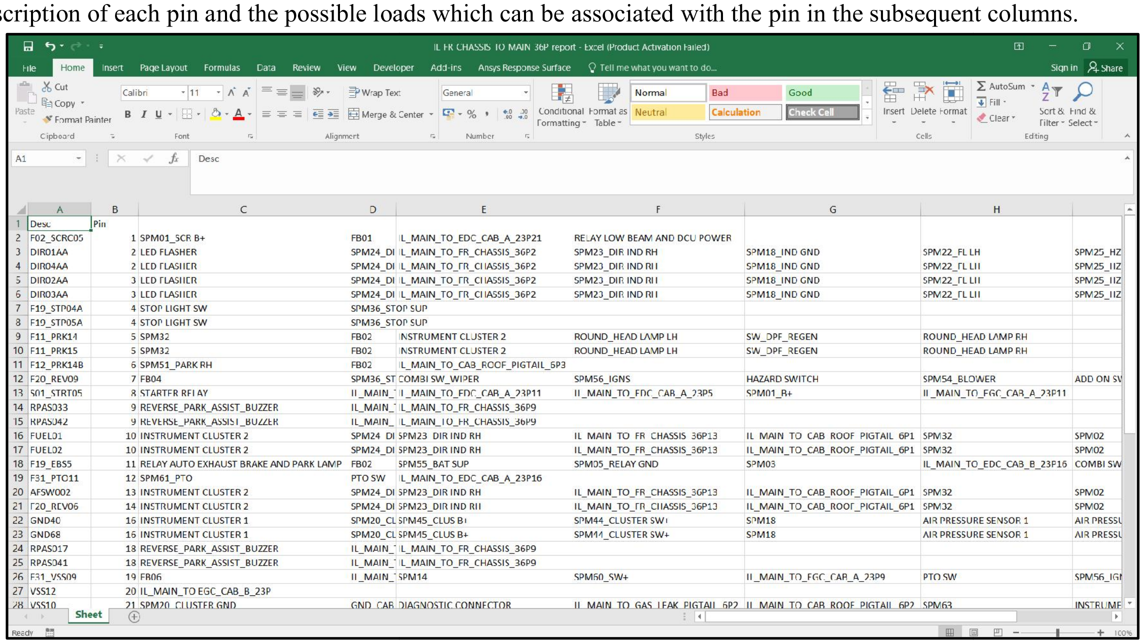


Fig 3.2.4.1

3.2.5 Final Output

The final output (Fig 4.2.5.1) is a excel file for each connector selected. A connector report file would contain the description of each pin and the possible loads which can be associated with the pin in the subsequent columns.



	A	B	C	D	E	F	G	H	
1	Desc	Pin							
2	F02_SCRC05	1	SPM01_SCR B+	FB01	IL_MAIN_TO_EDC_CAB_A_23P21	RELAY LOW BEAM AND DCU POWER			
3	DIR01AA	2	LED FLASHER	SPM24_DI	IL_MAIN_TO_FR_CHASSIS_36P2	SPM23_DIR IND RH	SPM18_IND GND	SPM22_FL LH	SPM25_HZ
4	DIR04AA	2	LED FLASHER	SPM24_DI	IL_MAIN_TO_FR_CHASSIS_36P2	SPM23_DIR IND RH	SPM18_IND GND	SPM22_FL LH	SPM25_HZ
5	DIR02AA	3	LED FLASHER	SPM24_DI	IL_MAIN_TO_FR_CHASSIS_36P2	SPM23_DIR IND RH	SPM18_IND GND	SPM22_FL LH	SPM25_HZ
6	DIR03AA	3	LED FLASHER	SPM24_DI	IL_MAIN_TO_FR_CHASSIS_36P2	SPM23_DIR IND RH	SPM18_IND GND	SPM22_FL LH	SPM25_HZ
7	F19_STP04A	4	STOP LIGHT SW	SPM36_STOP SUP					
8	F19_STP05A	4	STOP LIGHT SW	SPM36_STOP SUP					
9	F11_PRK14	5	SPM32	FB02	INSTRUMENT CLUSTER 2	ROUND_HEAD LAMP LH	SW_DPF_REGEN	ROUND_HEAD LAMP RH	
10	F11_PRK15	5	SPM32	FB02	INSTRUMENT CLUSTER 2	ROUND_HEAD LAMP LH	SW_DPF_REGEN	ROUND_HEAD LAMP RH	
11	F12_PRK14B	6	SPM51_PARK RH	FB02	IL_MAIN_TO_CAB_ROOF_PIGTAIL_6P3				
12	F20_REV09	7	FB04	SPM36_ST	COMBI SW_WIPER	SPM56_IGNS	HAZARD SWITCH	SPM54_BLOWER	ADD ON SV
13	S01_STRT05	8	STARTER RELAY	IL_MAIN_	IL_MAIN_TO_EDC_CAB_A_23P11	IL_MAIN_TO_EDC_CAB_A_23P5	SPM01_B+	IL_MAIN_TO_EGC_CAB_A_23P11	
14	RPAS033	9	REVERSE_PARK_ASSIST_BUZZER	IL_MAIN_	IL_MAIN_TO_FR_CHASSIS_36P9				
15	RPAS042	9	REVERSE_PARK_ASSIST_BUZZER	IL_MAIN_	IL_MAIN_TO_FR_CHASSIS_36P9				
16	FUEL01	10	INSTRUMENT CLUSTER 2	SPM24_DI	SPM23_DIR IND RH	IL_MAIN_TO_FR_CHASSIS_36P13	IL_MAIN_TO_CAB_ROOF_PIGTAIL_6P1	SPM32	SPM02
17	FUEL02	10	INSTRUMENT CLUSTER 2	SPM24_DI	SPM23_DIR IND RH	IL_MAIN_TO_FR_CHASSIS_36P13	IL_MAIN_TO_CAB_ROOF_PIGTAIL_6P1	SPM32	SPM02
18	F19_EBS5	11	RELAY AUTO EXHAUST BRAKE AND PARK LAMP	FB02	SPM55_BAT SUP	SPM05_RELAY GND	SPM03	IL_MAIN_TO_EDC_CAB_B_23P16	COMBI SW
19	F31_PTO11	12	SPM61_PTO	PTO SW	IL_MAIN_TO_EDC_CAB_A_23P16				
20	AFSW002	13	INSTRUMENT CLUSTER 2	SPM24_DI	SPM23_DIR IND RH	IL_MAIN_TO_FR_CHASSIS_36P13	IL_MAIN_TO_CAB_ROOF_PIGTAIL_6P1	SPM32	SPM02
21	F20_REV06	14	INSTRUMENT CLUSTER 2	SPM24_DI	SPM23_DIR IND RH	IL_MAIN_TO_FR_CHASSIS_36P13	IL_MAIN_TO_CAB_ROOF_PIGTAIL_6P1	SPM32	SPM02
22	GND40	16	INSTRUMENT CLUSTER 1	SPM20_CL	SPM45_CLUS B+	SPM44_CLUSTER SW+	SPM18	AIR PRESSURE SENSOR 1	AIR PRESSU
23	GND68	16	INSTRUMENT CLUSTER 1	SPM20_CL	SPM45_CLUS B+	SPM44_CLUSTER SW+	SPM18	AIR PRESSURE SENSOR 1	AIR PRESSU
24	RPAS017	18	REVERSE_PARK_ASSIST_BUZZER	IL_MAIN_	IL_MAIN_TO_FR_CHASSIS_36P9				
25	RPAS041	18	REVERSE_PARK_ASSIST_BUZZER	IL_MAIN_	IL_MAIN_TO_FR_CHASSIS_36P9				
26	F31_VSS09	19	FB06	IL_MAIN_	SPM14	SPM60_SW+	IL_MAIN_TO_EGC_CAB_A_23P9	PTO SW	SPM56_IGI
27	VSS12	20	IL_MAIN_TO EGC_CAB_B_23P						
28	VSS10	21	SPM20_CLUSTER GND	GND_CAB	DIAGNOSTIC CONNECTOR	IL_MAIN_TO_GAS_LEAK_PIGTAIL_6P2	IL_MAIN_TO_CAB_ROOF_PIGTAIL_6P2	SPM63	INSTRUME

Fig 3.2.5.1

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.53

Volume 4, Issue 2, July 2024

IV. LIMITATIONS

Unexpected table layouts, merged cells, or missing headers can pose challenges for automated processing, necessitating manual intervention.

The substantial size difference between tables might require tailored extraction approaches to ensure complete and accurate data capture.

Non-uniform line intensities can impact readability and automated recognition of table boundaries, potentially leading to data errors.

An uneven connector structure and lack of data can lead to discrepancies in the process of generating the report.

V. SCOPE OF IMPROVEMENT

To counter the above limitations, certain improvements mentioned below can be employed further.

Develop a robust and engaging graphical user interface (GUI) capable of displaying PDF documents. The selection process should be automated, with the option for manual assistance.

Implement a function in the graphical user interface (GUI) to modify inconsistencies in the data.

The project has the potential to be enhanced in order to automatically infer the bill of materials for the necessary components for the wire harness design.

VI. CONCLUSION

The project's alignment with Industry 4.0 principles is evident in automation to optimize design processes. The conventional manual method for pigtail harness design, however useful, has inherent limits in terms of time consumption and vulnerability to errors. By reducing the need for human intervention in repetitive and error-prone tasks, the project frees up human resources to focus on more complex, value-added activities and decision making. The time taken in drafting the final wiring harness table using AI has been reduced to 20-30 minutes compared to traditional manual methods which take about 5 working days. This shift not only improves productivity but also fosters innovation and adaptability in design and development. In summary, this project, through the strategic application of RPA and AI, embodies the transformative potential of Industry 4.0, driving efficiency, accuracy, and innovation in design processes.

REFERENCES

[1] Pemarathne, Punsisi & Fernando, T.G.I.. (2016). Wire and cable routings and harness designing systems with AI, a review. 1-6. 10.1109/ICIAFS.2016.7946575.

[2] Pradhan, Ajay. (2011). Current Trends in Automotive Wire Harness Design.

[3] Yildiz, Burcu & Kaiser, Katharina & Miksch, Silvia. (2005). pdf2table: A Method to Extract Table Information from PDF Files.. 1773-1785.

[4] Pradhan, Ajay. (2012). OPTIMISING THE DESIGN OF WIRE HARNESS.

[5]Castorani, Vincenzo & Cicconi, Paolo & Mandolini, Marco & Vita, Alessio & Germani, Michele. (2018). A method for the cost optimization of industrial electrical routings. Computer-Aided Design and Applications. 15. 1-10. 10.1080/16864360.2018.1441241.

[6] Silva, J. & Silva, L. & Barros, M. & Santos, T. & Julião, G. & Santos, J. & Ferreira, F.F.V.M.. (2024). Data Analytics Applied to Automotive Wiring Harness (Electrical Distribution Systems). 10.4271/2023-36-0058.

[7] T. Karlsson, E. Åblad, T. Hermansson, J.S. Carlson, G. Tenfält, Automatic Cable Harness Layout Routing in a Customizable 3D Environment,Computer-Aided Design,Volume 169,2024,103671, ISSN 0010-4485.

[8] Conru, AB, & Cutkosky, MR. "Computational Support for Interactive Cable Harness Routing and Design." *Proceedings of the ASME 1993 Design Technical Conferences. 19th Design Automation Conference: Volume 1 — Mechanical System Dynamics; Concurrent and Robust Design; Design for Assembly and Manufacture; Genetic Algorithms in Design and Structural Optimization*. Albuquerque, New Mexico, USA. September 19–22, 1993. pp. 551-558. ASME.

[9] Kamm, Simon & Veekati, Sushma Sri & Müller, Timo & Jazdi, Nasser & Weyrich, Michael. (2023). A survey on machine learning based analysis of heterogeneous data in industrial automation. Computers in Industry. 149. 103930. 10.1016/j.compind.2023.103930.

[10] Trommnau, Jerome & Kühnle, Jens & Siegert, Jörg & Inderka, Robert & Bauernhansl, Thomas. (2019). Overview of the State of the Art in the Production Process of Automotive Wire Harnesses, Current Research and Future Trends. Procedia CIRP. 81. 387-392. 10.1016/j.procir.2019.03.067.

[11] Masoudi, N., and Fadel, G. (July 20, 2021). "An Optimization Framework for the Design of Cable Harness Layouts in Planar Interconnected Systems." ASME. J. Mech. Des. January 2022; 144(1): 011701. https://doi.org/10.1115/1.4051685

[12] Saekyeol Kim, Shinyu Kim, Taeheok Choi, Taejoon Kwon, Tae Hee Lee, Kwangrae Lee, Automatic design system for generating routing layout of tubes, hoses, and cable harnesses in a commercial truck, *Journal of Computational Design and Engineering*, Volume 8, Issue 4, August 2021, Pages 1098–1114, https://doi.org/10.1093/jcde/qwab034

[13] Kobayashi, M., Hirano, Y., & Higashi, M. (2013). Optimization of Assembly Processes of an Automobile Wire Harness. Computer-Aided Design and Applications, 11(3), 305–311. https://doi.org/10.1080/16864360.2014.863500

[14] Ng FM, Ritchie JM, Simmons JEL. The design and planning of cable harness assemblies. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture. 2000;214(10):881-890. doi:10.1243/0954405001517964

[15] Park H, Cutkosky MR, Conru AB, Lee S-H. An agent-based approach to concurrent cable harness design. Artificial Intelligence for Engineering Design, Analysis and Manufacturing. 1994;8(1):45-61. doi:10.1017/S0890060400000457

[16] Moore, S., "Modeling and Optimizing Wire Harness Costs for Variation Complexity," SAE Technical Paper 2016-01-0107, 2016, https://doi.org/10.4271/2016-01-0107.

[17] P. Gao, J. Wen and Y. Hu, "Simulation and optimization of manufacturing process for aircraft harness," *2014 IEEE 7th Joint International Information Technology and Artificial Intelligence Conference*, Chongqing, China, 2014, pp. 550-554, doi: 10.1109/ITAIC.2014.7065111.

[18] Han, N, & Guo, L. "The Research on Routing Optimization Method Using Undirected-Graph in Cable Harness Design." *Proceedings of the ASME 2017 International Mechanical Engineering Congress and Exposition. Volume 11: Systems, Design, and Complexity*. Tampa, Florida, USA. November 3–9, 2017. V011T15A006. ASME. https://doi.org/10.1115/IMECE2017-71282

[19] Wei, Xing & Croft, Bruce & Mccallum, Andrew. (2006). Table extraction for answer retrieval. Information Retrieval. 9. 589-611. 10.1007/s10791-006-9005-5.

[20] Wiechork, Karina & Charão, Andrea. (2021). Automated Data Extraction from PDF Documents: Application to Large Sets of Educational Tests. 10.5220/0010524503590366.

[21] Hassan, Tamir & Baumgartner, Robert. (2005). Intelligent Text Extraction from PDF Documents. 2- 6. 10.1109/CIMCA.2005.1631436.

[22] Ahmad, Riaz & Afzal, Muhammad & Qadir, Muhammad Abdul. (2016). Information Extraction from PDF Sources Based on Rule-Based System Using Integrated Formats. 641. 293-308. 10.1007/978-3-319-46565-4_23.

[23] Zozaya-Gorostiza, C., Sudarbo, H., Estrada, L.F. (1994). Use of Genetic Algorithms to Optimize the Cost of Automotive Wire Harnesses. In: Baeza-Yates, R. (eds) Computer Science 2. Springer, Boston, MA. https://doi.org/10.1007/978-1-4757-9805-0_12

[24] Ioana Stefan (Iorga), Adrian Constantin Popescu, Cicerone Laurentiu Popa, Tiberiu Gabriel Dobrescu, Costel Emil Cotet, Research regarding assembly flow optimization of wiring harness in automotive industry ,MATEC Web Conf. 343 02003 (2021) ,DOI: 10.1051/matecconf/202134302003

[25] WEI, WEI, "Complexity management of vehicle wiring harnesses: An optimized model to analyse trade-offs between product and manufacturing costs" (2012). Electronic Theses and Dissertations. Paper 4846.

[26] Marie-Sklaerder Vié, Nicolas Zufferey, Jean-François Cordeau, Solving the Wire-Harness Design Problem at a European car manufacturer, European Journal of Operational Research,Volume 272, Issue 2,2019, Pages 712-724, ISSN 0377-2217, https://doi.org/10.1016/j.ejor.2018.06.047.

[27] Nasution, Mahyuddin. (2020). Industry 4.0. IOP Conference Series: Materials Science and Engineering. 1003. 012145. 10.1088/1757-899X/1003/1/012145.

[28] Jan, Zohaib & Ahamed, Farhad & Mayer, Wolfgang & Patel, Niki & Grossmann, Georg & Stumptner, Markus & Kuusk, Ana. (2022). Artificial Intelligence for Industry 4.0: Systematic Review of Applications, Challenges, and Opportunities. Expert Systems with Applications. 216. 119456. 10.1016/j.eswa.2022.119456.

[29] https://betterprogramming.pub/extracting-tables-from-images-in-python-made-easy-ier-3be959555f6f

[30] https://towardsdatascience.com/a-table-detection-cell-recognition-and-text-extraction-algorithm-to-convert-tables-to-excel-files-902edcf289ec

[31] https://tabula-py.readthedocs.io/en/latest/tabula.html

[32] https://tesseract-ocr.github.io/tessdoc/

[33] https://docs.opencv.org/4.x/

[34] https://pymupdf.readthedocs.io/en/latest/