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Copilot and CAN-Bus Connected ECUs Integrated Scenarios for Automotive Diagnosis, Enhanced by Scan Tools, Conversational Agents and AI Technologies

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Abstract

The evolution of automotive technologies brought into play the large amount of hardware and software devices, with their subsequent software frameworks and programming languages, as well as the adoption of Cloud environments for data storage, management and analysis. In this general context, specialists are faced with information overload and users have become more and more confused about the measures that should be taken in order to optimize the vehicle use, maintenance and repair. AI technologies could greatly help both users and specialists in their vehicular interactions. On the one hand, AI could give very good answers as long as the information on which the responses are based is correct and complete. On the other hand, the questions should be well formulated, clear and specific in order to maximize the accuracy and correctness of the answers. This paper aims at building an algorithm of combining ISO 15765-4 and SAE J1979 compliant professional scan tools technologies with Microsoft Copilot for evolving the automotive diagnosis process. The resulting algorithm consists of a set of procedures and steps that should be followed, for building an intelligent agent. This agent incorporates a knowledge base that includes maintenance and repair manuals, diagnosis tests results and previous experience. In this way, the vehicle maintenance and repair activities should gain a higher level of efficiency.

Keywords: ECUs; A.I. conversational agents; vehicle communication interfaces (VCIs); diagnostic trouble codes (DTCs); vehicle diagnosis.

1 Introduction

Intelligent vehicle development demands fluent interactions between users and their environment, driving the need for more interactive and intuitive user experiences. To meet these expectations, automotive design has embraced advanced development methodologies, incorporating diverse electronic systems that enhance safety, usability, fuel and energy efficiency.

Consequently, the road vehicle architectures became very complex owing to hardware, software and network protocols. In many situations, the errors and unwanted vehicular behaviours become very difficult to determine and to adjust. This process requires that new tools and technologies should be provided, in addition to the traditional scan tools and databases.

Computer scientists and software engineers play a major role in the modelling and analysis of such complex systems, while AI agents should provide a reliable support for the specialists to ensure accurate diagnostic and to complete the maintenance and repair procedures in a productive way.

One of the objectives of this research is to analyse and describe the potential benefits and opportunities of Cloud and Internet technology adoption in intelligent vehicle diagnosis based on CAN network data analysis [1, 2] with the support of AI technologies and Microsoft Copilot. We believe that this study should provide reliable support for both the final users and specialists in vehicle maintenance and service.

While our explorations have been confronted with the lack of documentation that should have been openly provided by the Automotive industry and TIER1 equipment manufacturers for research, we still managed to drawup some scenarios in which both the final users and the automotive specialists may easily retrieve themselves. As technology becomes more and more complex, the typologies of errors—DTCs (Diagnostic Trouble Codes) and faults have also numerically and typologically diversified.

Recent studies related to vehicle fault diagnosing within Automotive R&D are focused on using generative and even agentic AI [3, 4], machine learning ML, and deep learning DL [5, 6]. The educational system must relate to automotive technological advances, to supply the labour market with specialists and to support the advancement in research. These processes require the adoption of new learning environments and techniques such as mixed reality, gamification [7, 8] and immersive technologies.

Many behaviours of vehicle sub-systems are to be studied only by manufacturer specific or TIER1 software and hardware equipment which brings into light the need of a more efficient data acquisition and processing operational procedures. A particular challenge, that we managed to overcome has been to comprise the research methodology from the field of Software Engineering and to adapt it in the Automotive Engineering research, with the support of Cloud and AI.

The AI scenarios could become a reliable solution for diagnosis. One reason might be as in [9] review, which concludes that OBD (On-board diagnostics) systems may not adequately distinguish between minor and major vehicle failures. Therefore, improved methods and techniques for better tracking and identifying failures are needed by the industry.

We shall go forward in describing the DTCs classification according to [10]. The ISO 27145 standard implements for worldwide policies of harmonizing the possibilities of communication with a road vehicle, by referring to all layers of the OSI model.

This standard has the possibility of evolution based on two separate approaches: (i) diagnosis over Controller Area Network and (ii) diagnosis over IP. This standard defined the diagnostic trouble codes definitions to be identifiable by various diagnostic devices.

The diagnosis [11] procedures according to the principles stated in ISO 15765-4 [12] and SAE J1979 [13] should have further possibilities of being enhanced by means of AI. This approach requires the questions asked to the AI based on prior professional scanning and certain DTCs or combinations of DTCs. AI does not exclude at all the specialized opinion regarding vehicular diagnosis and maintenance.

Table 1 shows that some of the errors are self-explanatory, such as P0627, indicating that it is highly probable that a fuse has blown. Others, such as C1A63 and C00188 are totally confusing, in terms of explanation. They require that further tests should be carried on, in order to determine the origin of the errors. However, it is necessary to have additional information about the specific DTCs and in order to diagnose properly and not to rely on guessing, or even worse, to start replacing parts instead of determining the origin of the errors.

Family of the Code	**Description**	**Example**	**Explanation**
P	Powertrain-engine and gearbox	P02E8 P0627	Diesel intake air flow position sensor Fuel pump circuit open. It could show either a fuse burnt or a pump electric motor malfunction
C	Chassis	C1A63 C1778 C00188	Right Rear Initiator Power steering failure C00188
B	Body	B11F7 B118E00	Passenger Folding Mirror Motor Error Left front window, General Failure
U	User Network	U0231	Lost communication with rain sensor module

Table 1: DTC Classification.

Historical data play a very important role in vehicle diagnosis and fault prediction [14], while works as [15] intend to estimate actuator faults, based on sensor data. These data should be reliable in order to generate correct results and detect faults so as to exclude false positives.

In our study, the data obtained through sensors and the actuators behaviour is practically the foundation of the knowledge base of the intelligent agent. The number of false positives should be minimized as well. Our research approach is meant to be just a step forward in AI vehicle diagnosis scenarios and the results offered by the Copilot conversational agent should be further checked and validated by the specialists, to be compliant with the repair and maintenance procedures. Whether a new procedure is AI defined, this procedure should be checked and not taken for granted without further testing.

Our main contribution in this work involves the construction of an algorithm that includes Microsoft Copilot technology for efficient vehicle diagnosis, based on error codes obtained by means of the scanning process and the information available in the technical documentation.

A future direction of study should analyse the compliance with the SAE ISO 26262 Road vehicles—Functional safety standard. In [16] the road vehicles are described as cyber-physical systems that should be subjected to comprehensive analyses, from both safety and security.

Further discussion may lead to both, adaptation of the standard to the use of AI and how the AI diagnosis and repair recommended procedures should correspond to the standard. One certain aspect is that every procedure should ensure that the vehicle is safe for road exploitation, especially concerning the braking [17] and steering systems.

2 Research Methodology on Intelligent Vehicle Scanning and AI

The research methodology aims to adopt AI in the vehicle scanning and analysis, in order to reach a higher level of accuracy in tests, and also to reduce the level of undetermined situations, in vehicle maintenance and repair. This uncertainty is generated by situations in which the DTCs are confusing or even missing, and any further test could just be made based on guessing. This could lead to vehicles blocking repair shops, higher costs and the replacement of parts that could be mended, so as to reduce costs and owing to this indirectly contributing to environmental protection.

The conducted experiment presumed at first to collect data related to problems that vehicle maintenance and repair shops have been faced with, that generated a confusion and therefore increasing of maintenance time and costs. Initially, tests have been carried out by means of professional scan tools, such as AUTEL MK808 and WOW Snooper+ 5.0.0.12, with the latest updates. The scanning process was oriented towards many types of vehicles, by different manufacturers. Each scanning process provided valuable data for the analysis process.

The scanning process is not oriented only on DTC, it mainly studies vehicles behaviour in certain situations, and how that performance is reflected through data provided by the sensors and ECUs. The development of new vehicles deeply required the integration of more user interaction with the environment as well as a more interactive user experience.

Therefore, the design of vehicles has always required the adoption of new development methodologies, which included a greater variety of electronic systems, that ensured greater safety, higher usability (UX) and an increased fuel efficiency. At the same time, vehicle architectures have become more complicated, requiring rather computer scientists and software engineers to determine and to understand certain systems behaviours.

While at the beginning ECU systems were independently defined e.g., Bosch Mono Motronic for injection and ignition management, nowadays the computer systems—ECUs have become interconnected and distributed over the entire vehicle structure. Nowadays, we have standards, such as SAE J2534 [18] that make the interconnection between computers and vehicles feasible through J1962 connectors also known as OBD port connectors.

According to [19] a normal car embeds more than 100 million lines of source code, but this number will permanently grow. That means that architectural consolidation is needed with a reduced number of ECUs, but more powerful ones, usually each unit being responsible for one field. However, if each domain has a subsequent ECU, that unit gets data from all the inherited systems and should reply to them accordingly.

Our methodology presumes that the information gathered by vehicle testers and especially by SAE J2534 [18] pass-through devices is enriched by Artificial Intelligence and Cloud services.

The first step is to identify the problematic situations in which diagnostic errors or uncertainty were identified. There are situations where the results obtained from scanning can cause confusion, and specialists may not identify the path to follow for remedying defects or for eliminating abnormal behaviours. In Figures 1 and 2, these aspects have been graphically described.

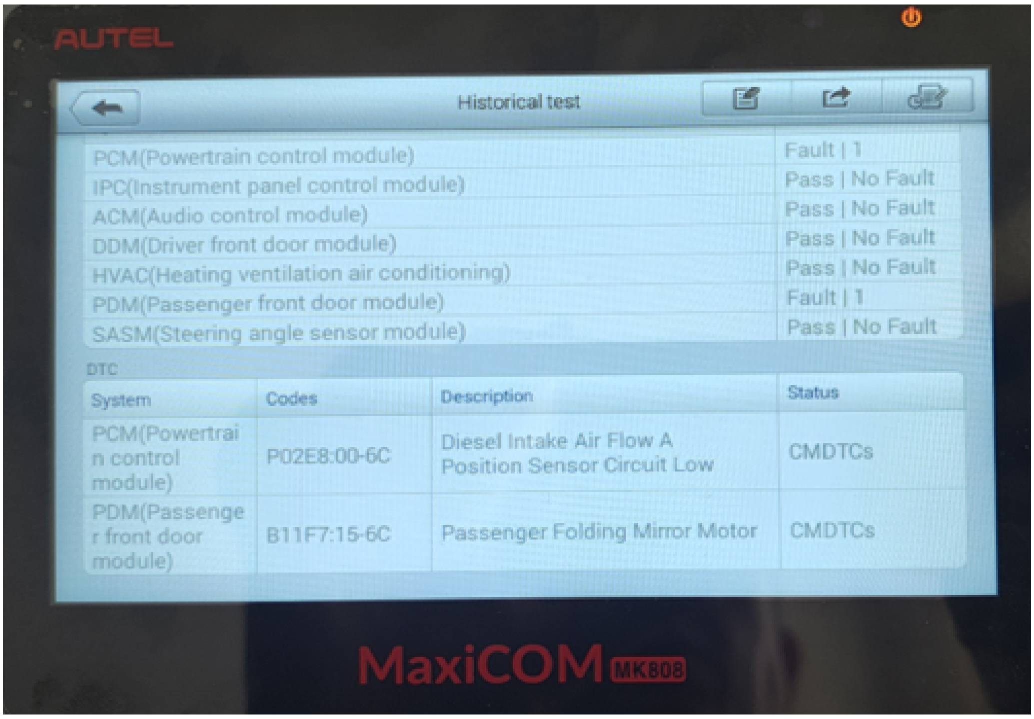

Figure 1: AUTEL MaxiCOM MK808 scanning—FORD MONDEO MK4.

The errors identified within the process of diagnosis are practically the starting point of further analysis and determination by means of Copilot and the subsequent services provided and trained through Chat GPT 4.

To simplify the approach, we will mainly consider a rather rare error, since only due to atypical behaviours of road participants can the side mirror motors malfunction. In these situations, which are

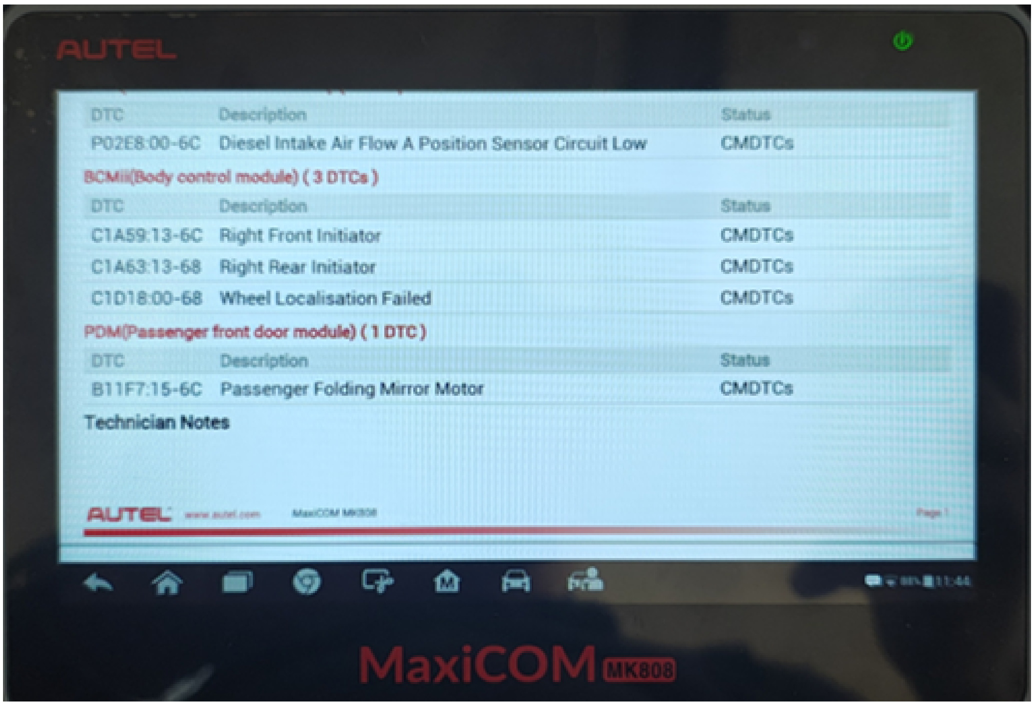

Figure 2: AUTEL MaxiCOM MK808 scanning report—FORD MONDEO MK4.

quite rare and do not involve the propulsion assembly, engine, and transmission, although the testing devices [20] are sophisticated, the information provided can be quite vague.

At this point, the maintenance specialists should decide whether to continue the process of diagnosis or to just replace the mirror electrical motor, and eventually the door control module with the subsequent electrical wiring and connectors. For sure, this would make the entire process very expensive for the customer and probably many of the components that would have been replaced, with or without any reason. This approach does not ensure that the problem would be solved in the end.

Some other situations, such as "crank no start" are even more difficult solved, especially when there are no fault codes (DTCs) associated with those situations. In such cases, the process of diagnosis goes typically to direct electrical measurements, while the information provided by the ECUs by the diagnosis port shows no direct relationship with the "crank no start" situation.

The second step involved reviewing the technical documentation, including the electronic and electrical schematics, to obtain a more straightforward image about the connected components and wiring for the vehicle body structure.

In this particular situation, for the B11F7 error code (DTC) the following assertions may be determined:

- erasing the code does not solve the problem, because it reappears, as a permanent error, not intermittent, which could bring more confusion to the diagnosis process.
- the schematics is difficult to study, time consuming and therefore it brings higher costs for the diagnosis process from the beginning of it;
- the process of disassembly of the entire vehicle door is also time consuming, expensive and does not guarantee the solution for the mirror problem.
- information from similar owners facing the same problem could be very helpful both for diagnosis and repair.
- gathering all the data could become a starting point for training an intelligent agent, e.g., Microsoft Copilot agent. This approach brings into light new conversational technologies [21] and

the potential benefits of their use in vehicle diagnosis and maintenance procedures optimization, as in Figure 3.

- In other scenarios, in which the powertrain, transmission or emission systems are studied, it is necessary to review the live scanning data, as in Figure 4, especially when the errors or the unwanted vehicle behaviours are intermittent. In those situations, live data streams could be analysed by means of Machine Learning and AI agents, that complement the know-how of the development and maintenance teams of specialists.

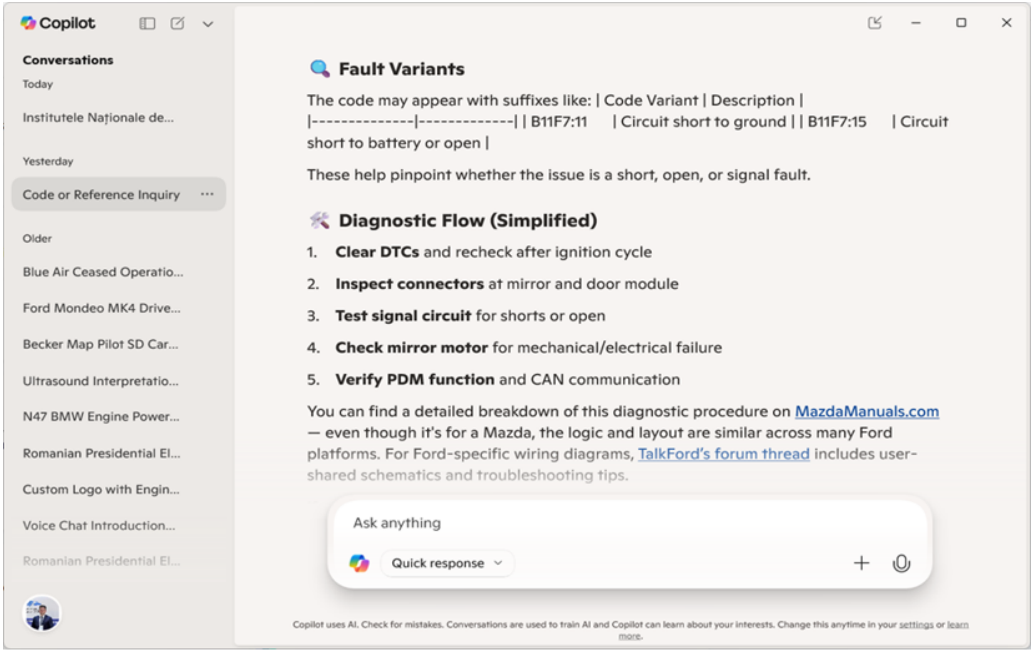

Figure 3: Microsoft Copilot result for the B1FF7 DTC.

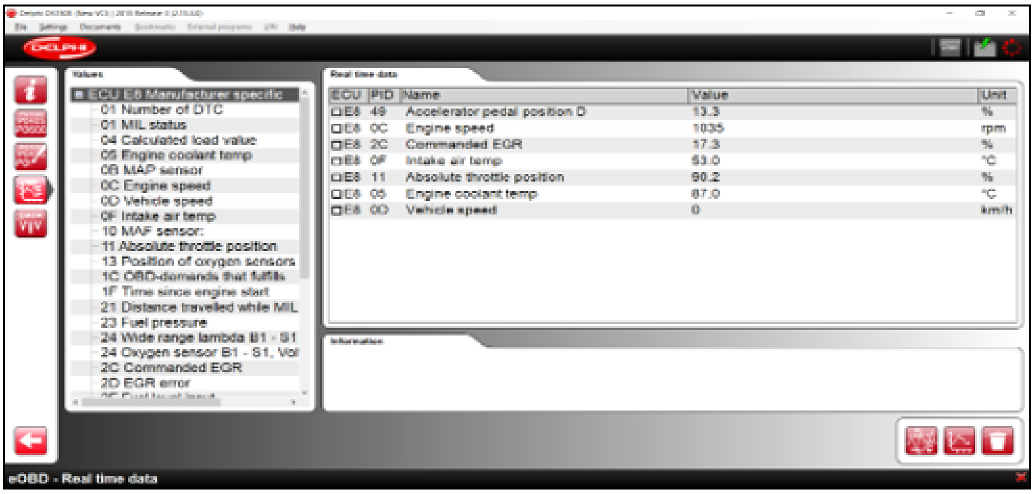

Figure 4: Real time data—Delphi DS150 E vehicle diagnostic tool.

The third stage involves a preliminary analysis of correlation between the data obtained by sensors and provided by the ECUs. This preliminary connection study could become one of the data inputs in the custom-built Copilot intelligent agent.

This correlation could be either numerically or graphically analysed, based on the real time data provided in Figure 5. Custom data lists may be defined as well, in relation to the modules that should be scanned and tested as well.

Figure 5: Real time data graphically shown—Delphi DS150E.

The fourth stage is to create an algorithm that formalizes the steps that should be taken to build a more productive diagnosis process. The following relations present the diagnosis algorithm improvement for the reliable integration of AI Technologies.

The scanning process is based on the analysis of the modular vehicular architecture that integrates all electronic control modules, and the networks associated to them, such as CAN, Lin, FlexRay and Automotive Ethernet.

We shall consider the following modules, as elements of a typed set

$$MO = Mo_1, Mo_2, \dots, Mo_k, \dots, Mo_{nrmod} \tag{1}$$

where:
Mo_k - module k within the vehicle architecture;
$nrmod$ - number of electronic control modules.

The vehicle diagnosis function is a set of procedures of evaluation for each electronic control module, each module generating a set of diagnostic trouble codes. The diagnostic function appears as a union of functions results applied to each electronic control module.

$$DIAG(Veh) = DIAG(Mo_1 \vee Mo_2 \vee \dots \vee Mo_k \vee \dots \vee Mo_{nrmod}) \tag{2}$$

where: $DIAG(Veh)$ - diagnostic function.

A DTC may be (i) self-explanatory (ii) partially self-explanatory (iii) undetermined by the scan tool. The indirect DTCs, such as a signal generated by an associated component not by the component itself, e.g., MAF sensors errors generated by EGR (exhaust gas recirculation) valve problems, should be considered partially self-explanatory.

In this case, we have

$$DTC(Mo_k) = \{SEDTCi_K \vee PSEDTCi_K \vee UDTCi_K\} \tag{3}$$

where:
$DTC(Mo_k)$ - the set of DTCs for the electronic module k;
$SEDTCi_K$ - the set of self-explanatory DTCs, counted by i for the module k;
$PSEDTCi_K$ - the set of partially self-explanatory DTCs, counted by i for the module k;
$UDTCi_K$ - the set of undetermined DTCs, counted by i for the module k.

The AI agent will include qualified questions in which the main focus is to "transform" the $PSEDTCi_K$ and $UDTCi_K$ into SEDTCi_KDTCs, by "decoration" with additional useful information brought by the AI. In other words, $SEDTCi_K$ should be maximized, while $PSEDTCi_K$ and $UDTCi_K$ should be minimized. Because ECUs are nodes in Controller Area Networks, they communicate via CAN busses, by sharing information captured by sensors about the vehicle working environment. A modern vehicle has around 60–70 ECUs and one million lines of code. The analysis of CAN networks presumes the referring to the ISO 11898-1 and ISO 11898-2 standards, corresponding to the Data Link and Physical Layers of OSI and with the Network Access layer of TCP/IP. The growing demand of data has brought into play the Automotive Ethernet standard, compliant with

IEEE 802.3. In [22] some issues related to checking and avoidance of vulnerabilities for automotive architectures are presented:

- the code for both systems and infrastructure is very complex, carried by the Tier1 suppliers and manufacturers:
- code generators are used, such as Real Time Embedded Coder from Mathworks [23] and C++ compliant with AUTOSAR [24] remains one of the most important programming languages;
- simulation tools allow the model-based development of automotive software and ensures automatic generation of ECU production code based on real-time requirements;
- automatic code generators introduce problems to be tackled further, reduce coding time but also need to adhere to the fast-changing requirements.

There are indeed benefits of automated coding, but the place of programmers cannot be taken by these CASE tools. We need specialists that have to understand the details of each implementation in order to insure the security and compliance. Tests assume both static and dynamic analysis of code and all the potential issues must be identified and solved before product launching. Sometimes the issues are identified after product launching and therefore users and maintenance shops are faced with recalls or situation in which there are errors or DTCs either partially or totally unknown. In this case AI algorithms should learn from experience, by means of current data and the step-by-step defects remediation procedures. Software updates or repair kits usually fixed these types of issues, but before the updates, the $PSEDTCi_K$ and $UDTCi_K$ must be addressed. In other situations, no updates that would solve the existing issues are available, while the information is only to be found on repair manuals, forums and user groups. In this situation, AI support should be very helpful as well, to find and summarize the existing knowledge and to offer reliable information to the users.

The algorithm that reflects this scenario considers the relations described in (1), (2) and (3). At first, the input and output data has been determined.

- INPUT: Vehicle data (scan data, live data, schematics, external knowledge, experience, agent know-how)
- OUTPUT: Optimized diagnosis plan + resolved DTC classification + optimal repair procedure => time and cost efficiency.

The following stage presumes the identification of the steps to be taken, in a synthetic procedure.

1. Data Acquisition – from vehicle scanning process, technical manuals and Vehicle Diagnosis agent
2. Module-based Diagnosis, as a unified process, that scans al the vehicle electronic modules
3. DTC identification
4. DTC Classification
5. AI Enrichment, as key element, based on the Copilot Vehicle Diagnosis Agent
6. Correlation Analysis (live data + ECUs)
7. Decision Support Output – such as DTC classification and optimal repair procedure, according to the DTC, that generates an increase in efficiency regarding diagnosis time and cost.

At this point, we shall draw up a pseudocode sequence, in order to describe in an analytical way, the steps from 1 to 7, based on Copilot Technology and manually adapted for the intelligent diagnosis scenario.

In algorithm 1, the procedure for intelligent diagnosis is synthetically presented, in the form of an algorithm written in pseudocode. The results in terms of procedure efficiency should look as follows:

Algorithm 1 DTC Algorithm - Synthesis

```
Algorithm AI_Vehicle_Diagnosis(Veh):
# Step 1 : Initialize
MO ← Identify_Modules(Veh)
Scan_Modules(Veh)
KnowledgeBase ← Load_AI_Knowledge(Agent)
Results ← ∅

#Step 2 : Scan all modules
for all M0_k in MO do
    DTC_set ← Scan_Module(Mo_k)
end for

#Step 3 : Classify DTCs
SEDTC_k ← ∅
PSEDTC_k ← ∅
UDTC_k ← ∅
for all DTC_i in DTC_set do
    if Is_Self_Explanatory(DTC_i) then
        add DTC_i to SEDTC_k
    else if Is_Partially_Explained(DTC_i) then
        add DTC_i to PSEDTC_k
    else
        the DTC is unidentified then
        add DTC_i to UDTC_k
    end if
end for

# Step 4 : AI Enrichment Phase
for all DTC_i in (PSEDTC_k ∪ UDTC_k) do
    ContextData ← Collect_Context(
      live_data, sensor_values,
      ECU_signals, schematics,
      historical_cases, user_reports)
    Insight ← AI_Analyze(DTC_i, ContextData, KnowledgeBase)
    if Insight resolves DTC_i then
        move DTC_i → SEDTC_k
    else if Insight partially clarifies then
        keep in PSEDTC_k
    else
        keep in UDTC_k
    end if
end for

# Step 5 : Correlation Analysis
Correlations ← Analyze_Correlation(live_data, sensors, ECUs)
Adjust classifications based on correlations
# Store results
Results[Mo_k] ← SEDTC_k, PSEDTC_k, UDTC_k, Correlations

# Step 6 : Global Optimization
DiagnosisPlan ← Generate_Repair_Strategy(Results)
return DiagnosisPlan, RepairProcedure
```

$$Duration(DiagT_i) > Duration(DiagT_{VDA}), i \in \mathbb{Z}_+ \tag{4}$$

$$CT(DiagT_i) > CT(DiagT_{VDA}), i, VDA \in \mathbb{Z}_+ \tag{5}$$

where

$DiagT_i$ – a regular diagnosis process at a certain moment i;

$DiagT_{VDA}$ – an intelligent diagnosis at the moment of the implementation of the Vehicle diagnosis agent;

$CT()$ – total cost function;

VDA – Vehicle Diagnosis Agent.

Relations 4 and 5 implicitly show the level of efficiency of the diagnosis process by minimizing the duration and costs generated by the implementation of the artificial intelligence agent. Studies regarding different levels of road vehicles autonomy supposed the integration of machine learning models, such as regression models, support vector machines and deep neural networks [25]. Our research methodology comes as a complementary approach, not directly oriented towards autonomy in terms of driving, but it might be further be oriented towards self-healing systems, that are enriched with self-diagnosis functionalities. However, there is quite a long distance until the objective of self-diagnosis and self-healing could become a regular phenomenon.

In comparison to the machine learning models, the implementation of conversational AI agents brings mode diverse data sources and create more comprehensive knowledge bases, taking into consideration the numerous data sources, such as scan tools data and software, error codes, live data analysis and data sets and other AI resources.

3 Building Conversational Agents for Automotive Maintenance and Repair Procedures Improvement

In this section, we shall start the building of the conversational agent, by using Microsoft Copilot technology. The use of chatbots and AI in vehicle diagnosis and maintenance could provide additional information, by "decorating" the $PSEDTCi_K$ and $UDTCi_K$ trouble codes with information that is not available in-place. This technology has the opportunity to learn from the previous experience of others having faced the same types of problems, each category of issues becoming a training set for the machine learning algorithms. In this scenario, the responses given by AI become more and more accurate in time, based on historical data sets. This approach is far more efficient than the coding of explicit rules for each situation in vehicle diagnosis and repair methods. The construction of a specialised intelligent agent reduces significantly the amount of inaccurate information. To this respect, the knowledge base plays a decisive role. All the information should be acquired and modelled through standardized procedures, while the safety and security standards should be updated as well for the inclusion of AI algorithms.

3.1 The $PSEDTCi_K$ — Partial Self-Explanatory DTC Copilot AI Scenario

One of the most uncommon situations, that may lead to undetermined procedures of repair consists of partially self-explanatory DTCs, that may lead to confusion and replacement of unnecessary parts. Things may become even worse, as even through the components being replaced, still the issue is not solved and therefore, the intermittent errors may reappear. The process repeats over and over again, the customer complaints not being properly addressed and consequences, such as higher costs, waste of resources, unhappiness and frustration remain at the end of the day.

In Figure 6, the construction of a Copilot intelligent agent is being described, the agent is called *Vehicle Diagnosis Agent*. The agent will be a generalized one, but if necessary, more specific agents may be built in the same way. The only difference should be the knowledge base with which the agent is trained.

The Copilot agent relies on Chat GPT4, as in Figure 7, and Open AI models which should provide more up to date and accurate responses to both customers and specialists questions. This means

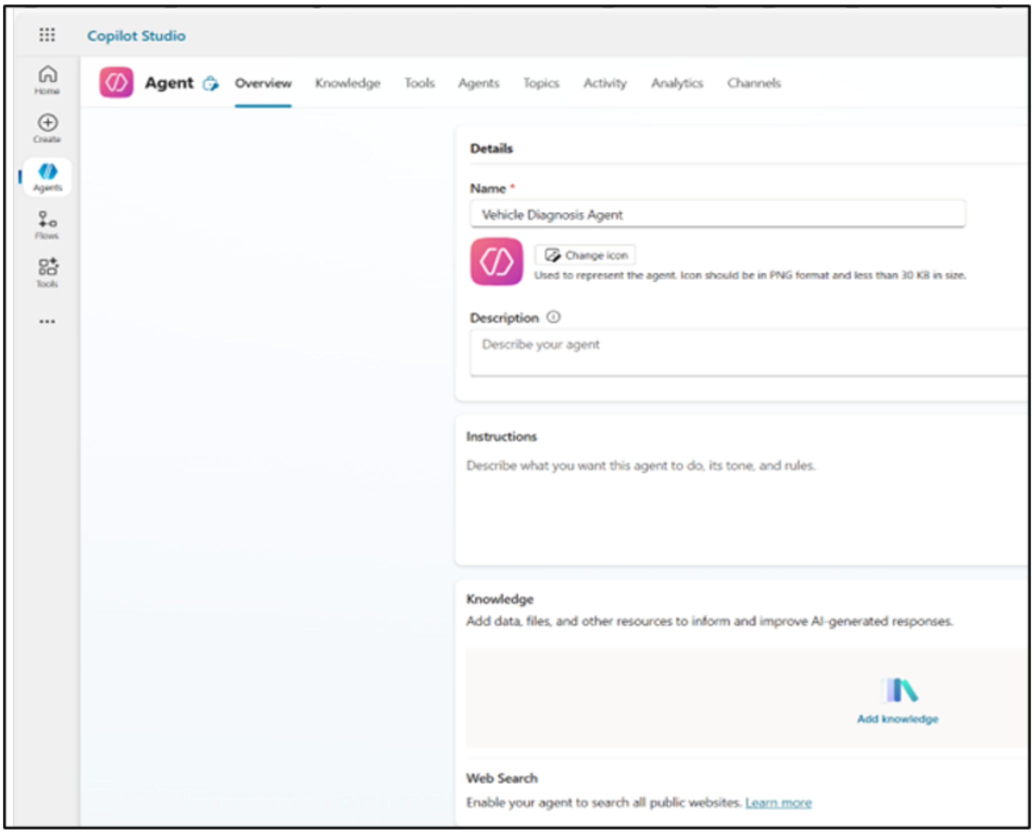

Figure 6: Building the Vehicle Diagnosis Agent in Copilot Studio.

that the questions should be correctly formulated, based on reliable and dependable information and should not rely only on subjectivity, suppositions, impressions, opinions or beliefs. In other words, the questions depend on the DTC codes, the vehicle brand, the type of propulsion, the previous experience of the maintenance staff.

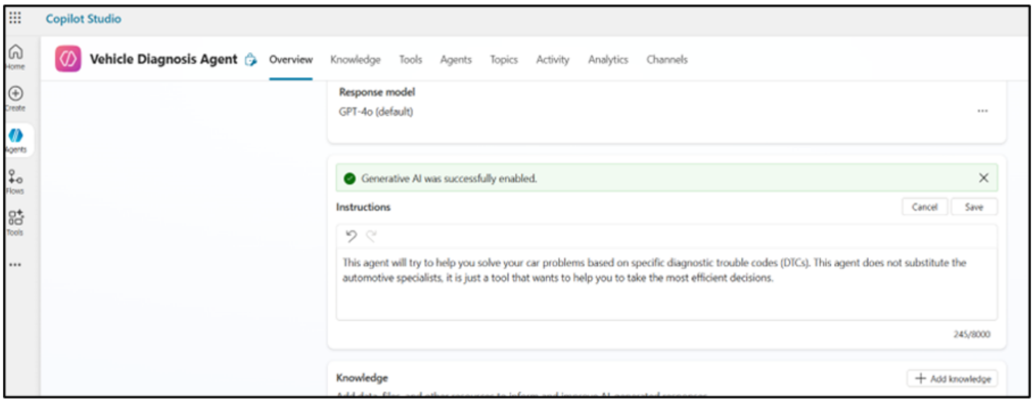

Figure 7: Vehicle diagnosis agent settings.

The *Vehicle Diagnosis Agent* is enriched with a description of the main objective. In our case *The agent will try to help you solve car problems, based on specific diagnostic trouble code (DTCs). The agent does not substitute the automotive specialists, it is just a tool that meant to help you take the most efficient decisions.*

Figure 8 presents the knowledge base and the activity map of the conversational agent. This data have been collected within the questioning session, previously asked by the users and answered by the conversational agent.

The questions/demands for the agents to ask are the following:

- What does the B11F7 DTC for a Ford Mondeo vehicle mean?

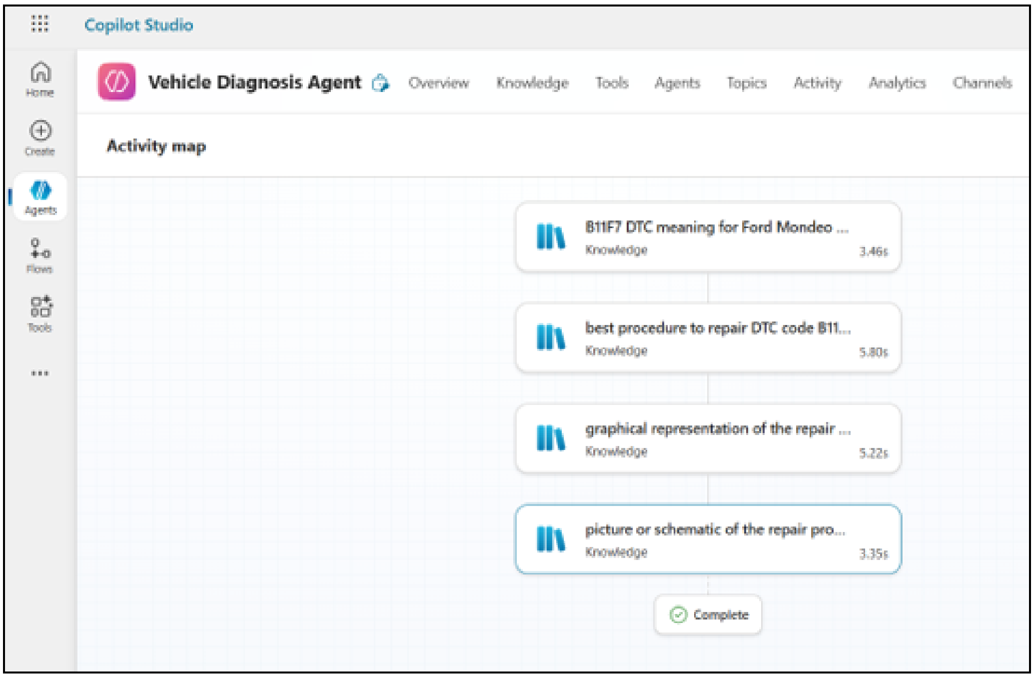

Figure 8: Intelligent agent activity map and knowledge base.

- Which are best procedures to repair a vehicle with B11F7 DTC?
- What does the graphical representation of the repair procedure look like?
- Can we have the picture or schematic aspects of the repair procedure?

Every question asked should be available for further similar studies and search phrases, and it trains the competence of the intelligent agent. The responses are given to the users in a matter of seconds, in comparison to the searching step by step in the technical documentation. This means that the technical documentation is very useful in training the intelligent agent, because it reads it and gets trained with it efficiently.

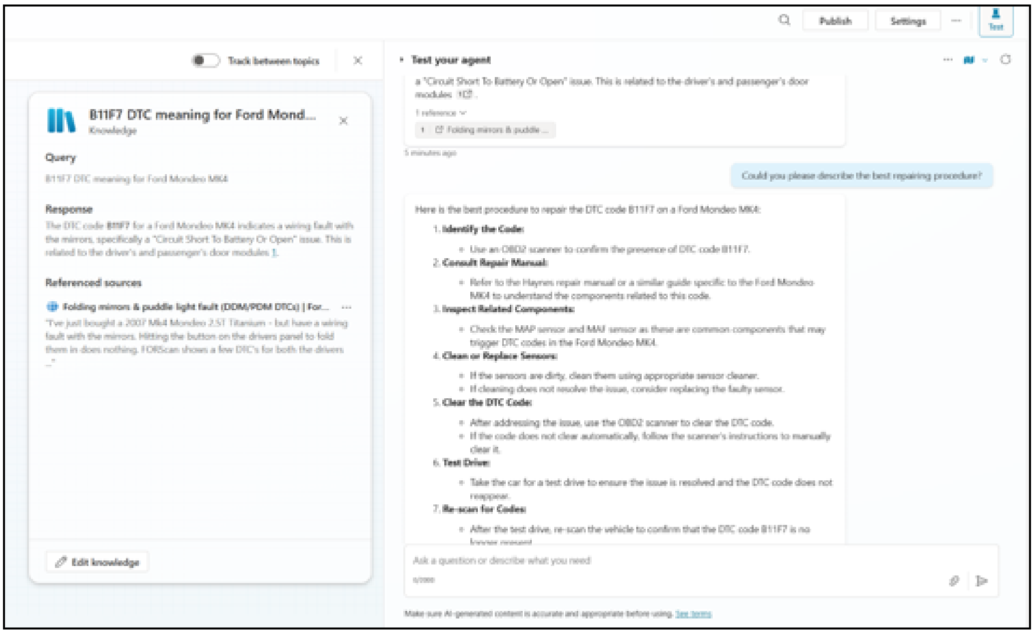

Figure 9: BIIF7 DTC intelligent agent response.

In Figure 9 there is shown that for the B11F7 DTC, there is a high probability of a wiring fault, related to the passenger door module. An algorithm or set of steps to repair the assembly of components in which the side mirror is integrated should be defined. The algorithm is not precise, because the question was too general, namely *Could you please describe the best repair procedure?* The correct question should be *Could you please describe the best repair procedure in the case of the BIIF7 DTC, for a Ford Mondeo MK4?*

In this situation, as shown in Figures 9 and 10 the intelligent agent for vehicle diagnosis offers the user a set of procedures, that should be completed to solve the problem of the vehicle. At first, the user is advised to scan the error code. This will bring about an amount of redundancy in the response. But the user is also advised to relate the existing error code, namely B11F7 with other codes. This teaches the user to make correlation between the trouble codes and therefore to determine correlations between the CAN connected components within the vehicle architecture. Practically, the automotive specialist is guided by the intelligent agent to make a deep diagnose and to research instead of guessing and replacing unnecessary parts.

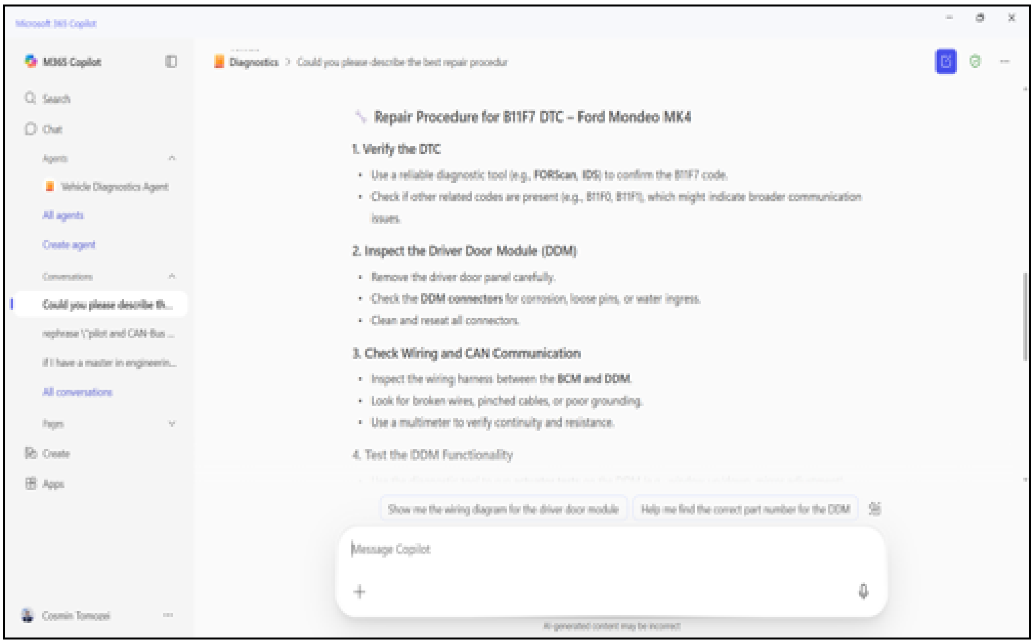

Figure 10: Intelligent agent recommendation.

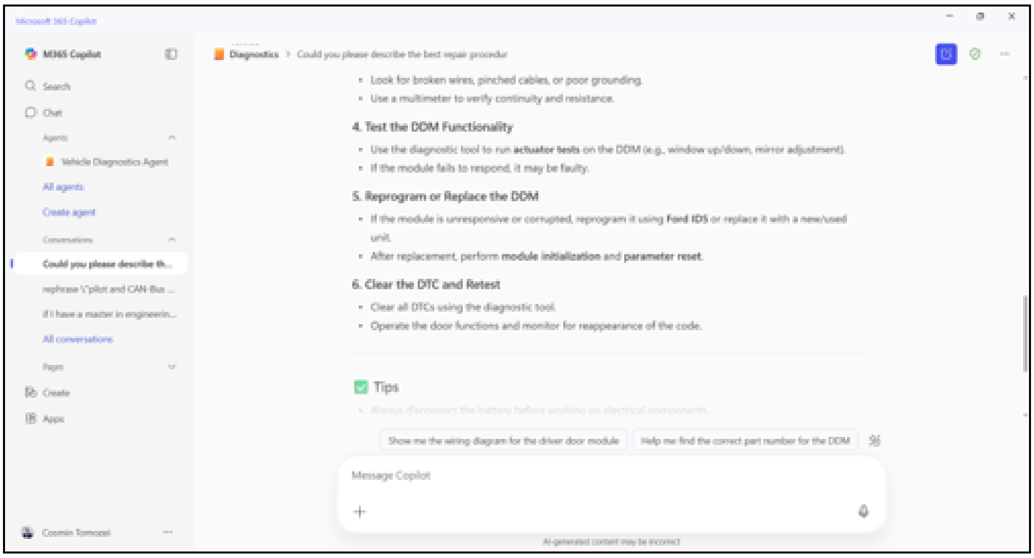

Figure 11: Tools and procedures recommendation.

In Figure 11, we find for the first time in this scenario the term actuator,which is very important for the analysis of systems functionalities. Before going to test the actuator on the test stand, the logical reasoning of the intelligent agent requires to check or test directly, with a multimeter, the resistance and continuity of the circuits, connecting the commands with the actuator and the actuator connecting the window electric motor.

The user asks again for a technical illustration or schematics for the door module wiring diagram. In Figure 12, some recommendations regarding the reliability of the documentation sources are presented.

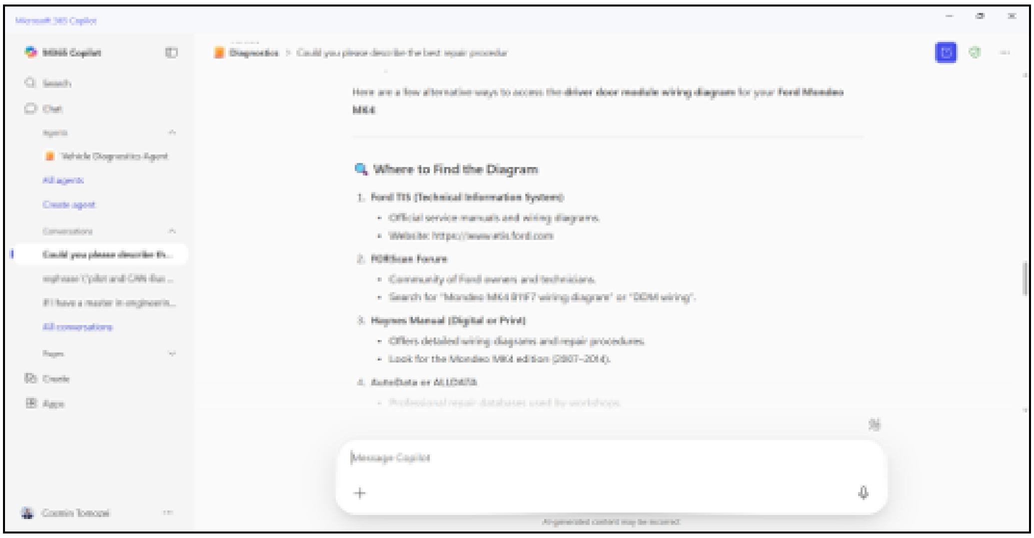

Figure 12: Technical documentation advisory.

At first, it gets a recommendation to search for the official documentation, such as FORD TIS (Technical Information System) [26], to owners' forums, such as FORScan Forum [27], Haynes Digital Manual [28] and AutoData [29]. This advisory procedure is very beneficial for the users, both owners and specialists and will enrich their automotive culture as well as teach them about the repair procedure and the necessary tools and components.

The user then asks for a detailed graphical explanation of the repair procedure. It is asked by the AI Copilot agent, meaning that the AI agent improved its training:

Would you like a technical-style diagram showing:

- wiring connections such as power, ground, CAN, LIN?
- connector pin layout ?
- module placement inside the door?

If the user replied with yes, then a graphical representation is shown, as in Figure 13. This will serve for comparison to the AutoData Schematics for the door module to get a more formal and accurate graphical representation. Still, the use of AI helps very much the users to make the diagnostics and repairing more efficient and in shorter time, but after consulting the results offered by AI, the specialists must also read the technical documentation, to be sure that the responses were correct and useful.

3.2 The $UDTCi_K$ - Undetermined DTC Copilot AI Scenario

In this section we are going to analyse a scenario in which the error code (DTC) is undetermined. It is not even partial self-explanatory, because the scan tool does not give any other information besides the code itself. These situations may occur when the vehicles are very new, the scan tools have not been updated, or the triggered error has not been implemented yet in the functions of the scanning software that one independent car repair shop may have. The scenario is based on a scanning procedure for a Volvo XC60 D5. The obtained DTC is *C00188* **- unknown fault code**. The vehicle has been scanned with two multibrand scanners and the results are the same. It means that we should

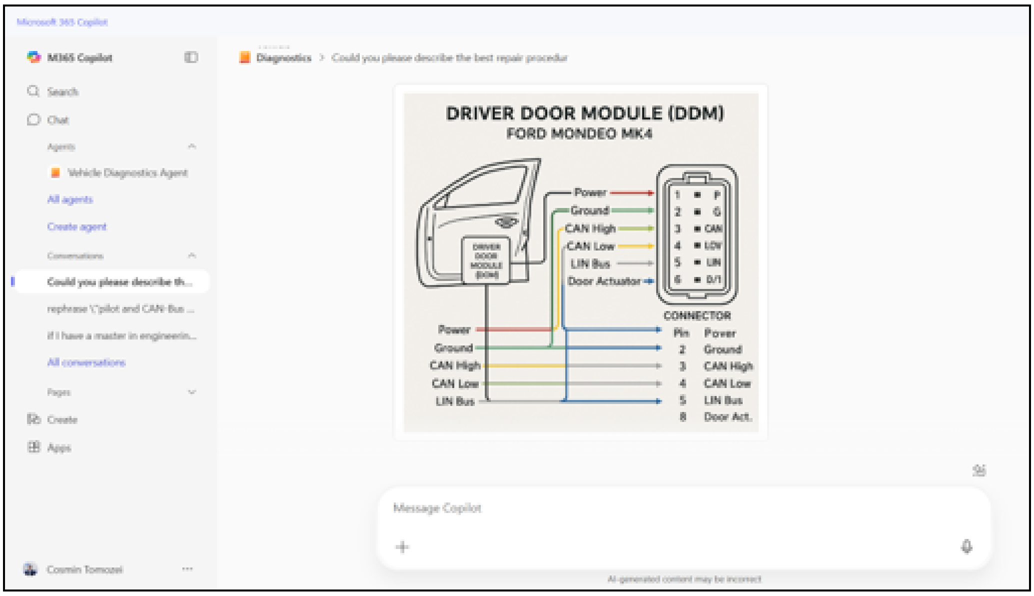

Figure 13: The $PSEDTCi_K$DTC becomes self-explanatory.

have gone forward with the diagnosis and use Artificial Intelligence and Copilot to determine the cause of this fault code. In Figure 14, the explanation about the previously undetermined trouble code is shown to the user, as further steps for more precise diagnosis are suggested.

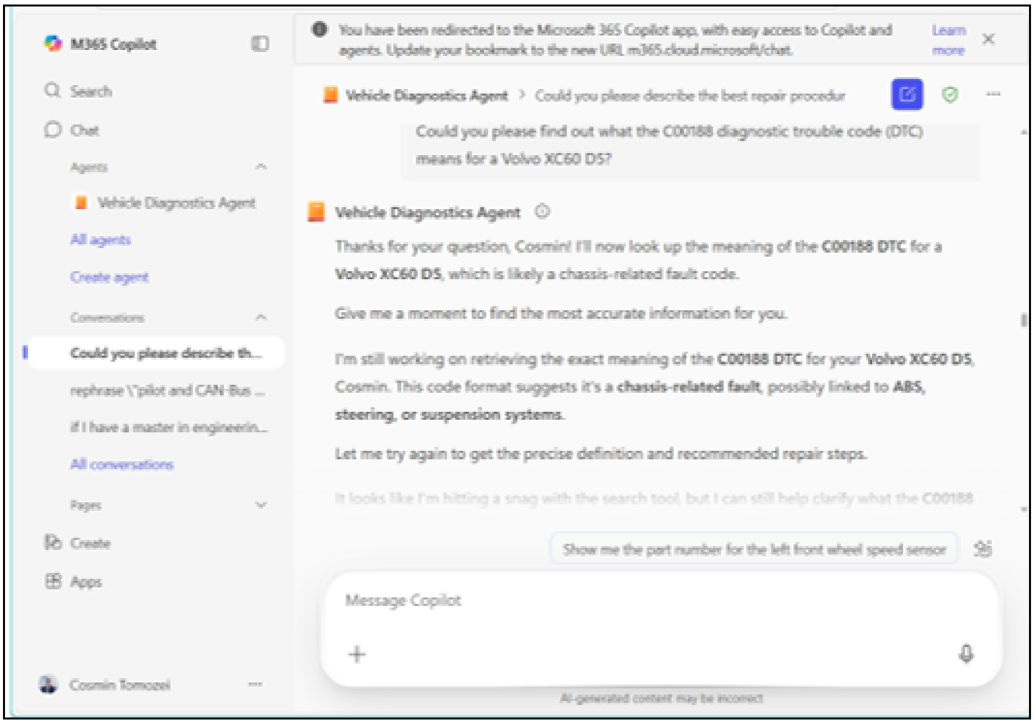

Figure 14: C00188 DTC identification (1).

When asking Copilot about the fault code, it states that it is a chassis related fault, which is correct. It also correlates the fault with the ABS, steering and suspension system. Consequently, when asked *"Show me possible symptoms for C00188 on XC60"* it finds out that the code has a general meaning, Figure 15, *"Left front wheel speed sensor circuit"*.

This information already turned out to be a solution for the transformation of an undefined error code into a partially self-explanatory one, that could be further tackled and fixed. It is a step forward for any automotive specialist faced with an undetermined error. Therefore, multiple further tests are to be carried out and check if the error persists or appears again after being erased. Intermittent

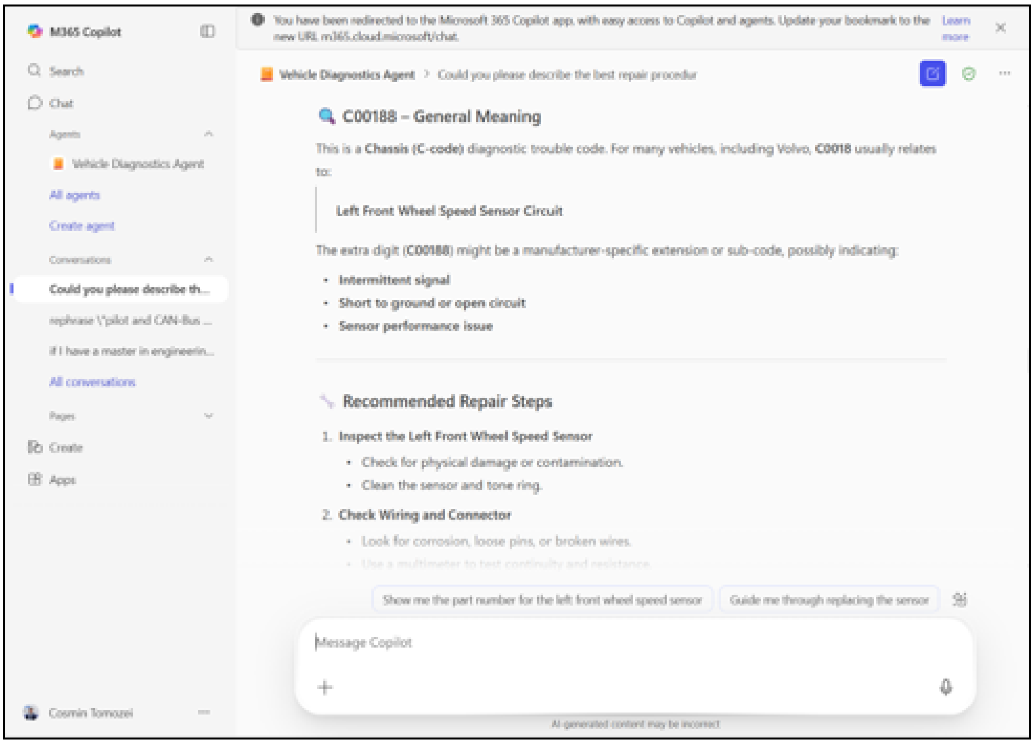

Figure 15: C00188 DTC identification (2).

errors are very difficult to capture and therefore it will take time to identify and to solve the problems. The costs of solving them, in terms of diagnosis and determination, is considerably higher than in the case of a permanent error.

In this case, according to the response AI agents gave, as in Figure 15, it shows there are some steps involving the inspection of the speed sensor and wiring and the cleaning of the components.

Plausible causes may be intermittent signals, due to physical damages of the wiring, or damaged connectors. Continuity and resistance testing by multimeter may lead to a solution. The verification of signals through the oscilloscope [7] may also show whether the sensor receives and transmits data properly to the corresponding electronic control unit.

The set of plausible causes may be reflecting the missing values [31] that the ECUs should analyze for the completion of the diagnosis process and the triggering of specific error codes. Having incomplete data leads to unknown fault codes that are further sent for analysis to the Copilot Agent.

The users, automotive specialists, could check if there are any symptoms from the ones Microsoft Copilot described, as in Figure 16. The customer complains should specify if the ABS system shown any warnings on the dashboard, or if any other warning lights or warning symbols have previously appeared. The conversation between the customer and the automotive specialist may have as a starting point the information that the Copilot intelligent agent offered and searched for a solution with a higher level of precision [32] within the technical documentation, based on the information the AI agent has provided. Consequently, the error code which was initially undetermined became fully documented and understood by both sides.

4 Conclusion

This paper analysed the complex process of vehicle diagnosis. The process requires technical training, skills, experience, analytical thinking and creativity. Automotive technologies become very complex, from hardware and software perspective and sometimes the information provided by scan tools and by customer complains proves to be incomplete and needs further tests and analyses. The integration of Cloud technology for data storage, management and processing offers the potential for the implementation of artificial intelligence technologies, such as Microsoft Copilot.

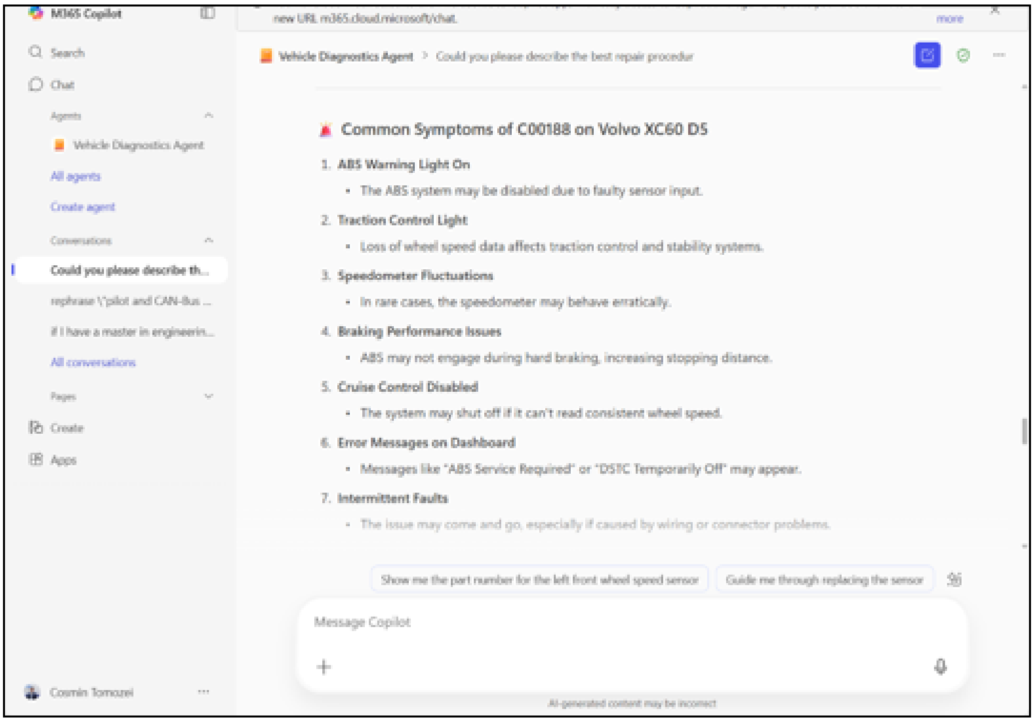

Figure 16: Symptoms of C00188 DTC.

The renewal and updating of standards, according to the present trends in the software industry should be further debated on, because the use of AI in vehicle development and maintenance should be compliant with the safety and security requirements and therefore leading to more responsibility towards a healthier environment. At this moment, the implementation of conversational agents in vehicle diagnosis may be considered at its early stage and every procedure and algorithm should be carefully supervised by specialists and researchers.

Regardless of the age, any well-made vehicle could at some point become a very illustrative subject of research. Any provided error code, partial self-explanatory or undermined may be further studied by means of intelligent agents and new ways of solving the issues more efficiently were determined. This study aims to offer dependable support in research procedures, for vehicle maintenance and repair. It has the possibility of improvement and of making the processes more efficient, in terms of time, accuracy and therefore costs.

The purpose of this research was to adopt AI in the vehicle scanning and analysis, to obtain better results in scanning and tests. The research aims to contribute to the reduction of the level of indeterminacy and confusion in vehicle diagnosis. There are situations in which the DTCs are unclear or even missing, and any further test could just be made based on guessing and replacing of parts, which is not the right way to go further.

The paper presented the way in which a dedicated agent was built, for the vehicle diagnosis and the way in which that agent has been used in two specific situations. Data obtained through scanning was either incomplete or missing in terms of explanation and it got enriched by means of artificial intelligence [30].

The use of AI has shown that the codes have been detected and qualified, testing procedures have been automatically defined, thanks to the symptoms that the intelligent agent identified. The agent asked automatically for questions that lead to the solution that was further implemented. The technical documentation provided the knowledge base for the intelligent agent.

Note:

The information, procedures, algorithms and techniques presented in this article are only on research purposes. No guarantees and recommendations are offered to the car owners or car repair shops. This work is meant to be addressed for research only.

References

[1] Saqib H.; Thippa R. G.; Praveen K.; Reddy M.; Swarna P. R.; Parimala M.; Chamitha D. A.; Madhusanka L. Autonomous vehicles in 5G and beyond: A survey, Vehicular Communications, Volume 39, 2023, 100551, ISSN 2214-2096, https://doi.org/10.1016/j.vehcom.2022.100551.

[2] Johansson, K.; Törngren, M.; Nielsen, L. Vehicle Applications of Controller Area Network. 2005, 10.1007/0-8176-4404-0_32.

[3] Naeem H.; Mustafizur R.; Devarajan R. Artificial Intelligence-Driven Vehicle Fault Diagnosis to Revo-lutionize Automotive Maintenance: A Review, Computer Modelling in Engineering & Sciences 2024, 141(2), pp.951-996. https://doi.org/10.32604/cmes.2024.056022

[4] What Is the Future of the Automotive Industry with Agentic AI? https://www.gnani.ai/resources/blogs/top-automotive-ai-trends-redefining-customer-experience/ (accessed on 04 July 2025)

[5] Azevedo Takara, L.; Cocco Mariani,V.; Santos Coelho, L. Novel engine fault diagnosis framework based on machine learning and MiniRocket feature extraction using multi-correlation feature selection and predictive power score, Expert Systems with Applications, Volume 293, 2025,128662, ISSN 0957-4174, https://doi.org/10.1016/j.eswa.2025.128662.

[6] Mode, G.R.; Adversarial robustness of deep learning enabled industry 4.0 prognostics, 2020, https://doi.org/10.32469/10355/88952

[7] Tomozei, C.; Furdu, I.; Mâţă, L. Automotive sensors in classroom, guiding students for understanding complex architectures, 2022 IEEE Zooming Innovation in Consumer Technologies Conference (ZINC), Novi Sad, Serbia, pp. 73-76, 25-26 May 2022, doi: 10.1109/ZINC55034.2022.9840587.

[8] Furdu, I.; Tomozei, C.; Kose, U. Pros and Cons Gamification and Gaming in Classroom. BRAIN. Broad Research in Artificial Intelligence and Neuroscience, 8 (2), pp.56-62, 2017, https://brain2.edusoft.ro/index.php/brain/article/view/238 (accessed on 04 July 2025).

[9] Rasheed, R.; Qazi, F.; Dur e Shawar Agha; Ahmed, A.; Asif, A.; Shams, H. Machine Learning Approaches for In-Vehicle Failure Prognosis in Automobiles: A Review. VFAST Transactions on Software Engineering, 12(1), pp.169–182, 2024, https://doi.org/10.21015/vtse.v12i1.1713

[10] Bosch Automotive Electrics and Automotive Electronics: Systems and Components, Networking and Hybrid Drive, 2014, Springer Fachmedien Wiesbaden, pp. 1-9, ISBN 978-3-658-01784-2.

[11] Butilă, E.V.; Boboc, R.G. Mapping the Landscape of Romanian Automotive Research: A Bibliometric Analysis. Vehicles 2025, 7, 31. https://doi.org/10.3390/vehicles7020031

[12] https://www.iso.org/standard/67245.html (accessed on 04 July 2025)

[13] ZEVonUDS - Zero Emission Vehicle SAE J1979-3 Diagnostic Standard|Vector

[14] Ryu, YH., Lee, KW., Sung, DU. et al. Review of diagnosis technology for future mobility vehicle. JMST Adv. 5, 77–84 (2023). https://doi.org/10.1007/s42791-023-00056-8

[15] Meléndez-Useros M., Viadero-Monasterio F., Jiménez-Salas M., López-Boada M. J., Active steering fault diagnosis via integrated LSTM-based sensor detection and robust actuator fault estimation, Relia-bility Engineering & System Safety, Volume 265, Part A, 2026,111573, ISSN 0951-8320, https://doi.org/10.1016/j.ress.2025.111573

[16] Li, Y.; Liu, W.; Liu, Q.; Zheng, X.; Sun, K.; Huang, C. Complying with ISO 26262 and ISO/SAE 21434: A Safety and Security Co-Analysis Method for Intelligent Connected Vehicle. Sensors 2024, 24, 1848. https://doi.org/10.3390/s24061848

[17] Lin, Z., Ziyang, Z. (2023). Summary of Fault Diagnosis of Electric Vehicle Braking System. Proceedings of TEPEN 2022. TEPEN 2022. Mechanisms and Machine Science, vol 129. Springer, Cham. https://doi.org/10.1007/978-3-031-26193-0_18 (29)

[18] KVASER, Advanced connectivity and CAN solution for engineering, https://kvaser.com/about-can/can-standards/j2534/ (accessed on 20 July 2025)

[19] Bosch Mobility Solutions https://www.bosch-mobility-solutions.com/en/company/press-releases/software-and-electronics-expertise/, 2021 (accessed on 20 July 2025)

[20] AUTEL, Research and Development for Automotive Diagnosis, https://www.auteltech.com/u/cms/www/202405/21040935iehs.pdf (accessed on 04 July 2025)

[21] Allouch, M.; Azaria, A.; Azoulay, R. Conversational Agents: Goals, Technologies, Vision and Challenges. Sensors, 2021, 21, 8448. https://doi.org/10.3390/s21248448

[22] Raya, M., Hubaux, J.-P. (2007). Securing vehicular ad hoc networks. Journal of Computer Security, 15(1), 39–68.

[23] MATLAB Embedded Coder https://www.mathworks.com/products/embedded-coder.html (accessed on 23 July 2025)

[24] Automotive Open Systems Architecture, https://www.autosar.org/(accessed on 23 July 2025)

[25] Re, L., Yuhao, A., Zhenghua, L., Dengta, N., Jinlong, D. (2024). Fault Diagnosis Method of Launch Vehicle Based on Deep Neural Network Proceedings of 2024 Chinese Intelligent Systems Conference. CISC 2024. Lecture Notes in Electrical Engineering, vol 1285. Springer, Singapore. https://doi.org/10.1007/978-981-97-8658-9_54

[26] Ford Technical Information System, https://www.etis.ford.com(accessed on 23 July 2025)

[27] Forscan Forum, https://www.forscan.org/forum/(accessed on 23 July 2025)

[28] Haynes Digital Manual, https://haynes.com/en-gb/ford/mondeo/2008-2010-20-diesel-272455, Haynes Publishing Group, 2019, ISBN 178521442X.

[29] Audatex Autodata, https://www.solera.com/ (accessed on 24 July 2025)

[30] Md Naeem Hossain; Md Mustafizur Rahman; Devarajan Ramasamy. Artificial Intelligence Driven Vehicle Fault Diagnosis to Revolutionize Automotive Maintenance: A Review. Computer Modelling in Engineering & Sciences, Vol. 141, No. 2, pp. 951-996, 2024.

[31] Andrioaia, D, Găitan V, Pătruţ B., Furdu I (2024) - Comparative Performance Analysis of Filling Missing Values Algorithms in PdM Systems of UAV, BRAIN. Broad Research in Artificial Intelligence and Neuroscience, Vol. 15, No. 2, pp. 437-453.

[32] Shafique, S., Abid, S., Riaz, F., Ahmed, B., Khan, M., Younis, U., Hamza, A. (2025). CARL-ODD: A Vision Benchmark Dataset of Asia for On-Road Vehicle Detection and Recognition. BRAIN. Broad Research In Artificial Intelligence And Neuroscience, 16(4), pp. 169-184.

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