POLITECNICO DI TORINO

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Master degree thesis

Robotic platform for testing the Infotainment system of various vehicles

FCA Italy – Reliability & Infotainment Quality

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ABSTRACT

Robotics has evolved considerably in recent times, it is no longer a complex, sometimes tedious and unnecessary application of automation; if in past years robots were simply the "arms" or "legs" of a higher mind that was, and still is clearly, that of man, today robots have truly acquired their own "thought" albeit in an embryonic state but, therefore, with very large margins for growth. The advent of AI (an essential factor of Industry 4.0 and of the evolution of digital) and its automation application, Machine Learning, has upset the world of manufacturing and tends to expand more and more into other areas; this is the case of Quality and Testing in the automotive sector, which thanks to FCA (now Stellantis) will have an important robotics innovation, a truly innovative and technologically advanced application: a COMAU machine composed of two robots and instrumentation that makes it almost entirely autonomous thanks to the appropriate testing methodology combined with a decidedly remarkable hardware-software implementation.

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INTRODUCTION

The advent of robotics was an event that profoundly changed the face and history of humanity and, in particular, of the manufacturing industry starting from the second half of the twentieth century: in the 1960s the first industrial robots began to be produced and exploited in an increasingly widespread manner in many industrial sectors including the automotive industry which was one of the first to massively exploit the applications of robotics both in production and in assembly. Recently, that is from the early years of the twenty-first century, the automotive industry has begun to glimpse other hitherto unknown purposes in robotic applications: in particular, the need to massively test human-machine interaction systems have become increasingly frequent and the technological evolution of robots has made it possible to exploit their potential outside of manufacturing. At the same time, man-machine interaction systems in automotive applications have experienced exponential technological progress and, thanks to the use of today's robots, it is now possible to practice different types of activities, not only manufacturing, but also real testing of complex systems on motor vehicles, both on prototype batches that are carrying out validation processes and on batches of pre-series or series production vehicles.

Today the main application of human-machine interaction on a vehicle is certainly found in infotainment systems, that is a multifunctional system physically integrated into the vehicle and its own communication network, both intra and extra vehicular. In recent decades, this system has seen enormous technological and, consequently, application evolution, since simple integrations of radios in the vehicle's electrical and electronic system have been transformed into real communication centers between user, vehicle and the outside world. ; for this reason, the need to test this system has increasingly become a crucial point in the development and effective evaluation of the entire vehicle product: in fact, considering the current overview of today's automotive market, the infotainment system is one of the main factors which determine the quality perceived by the customer and the costs related to product development and implementation.

Based on this information, one of the largest world companies in the sector, i.e. FCA, has decided to invest and experiment with a new methodology for testing infotainment systems, combining the traditional checks by system specialists with the use of an innovative robotic platform, which is a tool that, for obvious reasons, allows you to increase the productivity and efficiency of testing operations in order to strengthen results and optimize the use of resources.

This new evolutionary process is also part of a technological revolution tending to an even greater coexistence of artificial intelligence and the work of man, called Industry 4.0.

The term Industry 4.0, coined around 2011 by the German ministry of education and research, concerns a roadmap to promote the digitalization and technological development of production and, more recently, other industrial processes. This new philosophy has taken on a global influence in recent years, pushing companies towards the integration of "smart" systems. In particular, however, the "4.0 revolution" does not only consist in integrating new machines and technologies but also in the adoption of a line of thought that tends to integrate factory systems and production chains by exploiting technology and connecting machines, people and Informative system.

The nine pillars of this new current are:

• Advanced manufacturing solution involves advanced systems for production, more specifically those for the automatic handling and manipulation of materials, such as AGVs and collaborative robots;

• Additive manufacturing, are 3D printers for the production of prototypes in plastic material and sophisticated metal components such as turbine blades;

• Simulation, consists in the use of data on operators, means of production and products that are used to find new solutions in a virtual way before they are actually implemented;

• Horizontal and vertical integration, which consists in developing means capable of ensuring vertical and horizontal integration between all the players in the production process;

• Industrial internet of things, concerns the need to insert computers incorporated into the machinery and a control system that makes them communicate and connect to the internet for the management of production from inside and outside;

• Cloud, concerns the way of managing and analyzing information through the implementation of cloud systems such as "online storage", the use of "cloud computing" and other external services;

• Cyber-security, precisely because of the new systems open to the outside and communicating with the internet, it is necessary to monitor the security of information that must not be altered due to the multiple interconnections;

• Big Data Analytics, are techniques that allow the management of large amounts of data from open systems for forecasting and prediction;

• Augmented reality, this is a new technology that will allow company personnel to physically interface with the real problems of their work in a virtual environment.

The main purpose of these factors is certainly the improvement of human working conditions for an even greater optimization of business and industrial activities.

The increase in the use of robotic systems within companies is strongly linked to the 4.0 revolution: industrial production is oriented towards achieving greater flexibility and responsiveness of processes and structures in the face of the increasingly stringent demand of the market for within which the demand for product customization has grown.

The human-machine interaction is practically affected by the philosophy of this thought: robots have the ability to perform routine activities with great speed, precision and repeatability without suffering fatigue or damage; however traditional control systems are limited from the point of view of managing unforeseen or unconventional situations.

Thanks to the constant search to make the human and artificial sphere communicate, a new robot technology has been developed that is able to cooperate with humans in a safe way and to guarantee 360-degree control of activities, also responding to impromptu situations in an effective and thus making them a source of resources and cases; although there are many open issues from the point of view of security, these systems are certainly already, and will increasingly be, destined to occupy a role of fundamental importance within the companies of the future.

In the common conception, the term "cobot" or "collaborative robot" means a sophisticated machine specifically designed to be able to work alongside humans without however representing a risk to their health.

Passive safety

All the features of robots designed for cooperation with humans are part of the so-called "passive safety". In these terms, the first very important factor for an outside observer is the weight difference compared to traditional machines. In order to share a space with the human being, it is necessary that they have a reduced mass, a goal widely achieved by the manufacturers thanks to the application of latest generation engines and components. In this way, almost always, the ratio between the weight of the robotic arm and its maximum capacity is reduced.

The shape and the materials used also play a very important role. For this reason, cylindrical shapes are preferred for the various parts of the arm which are composed of plastic and light metals very often covered with a layer of soft material. The extreme lightness of these robots therefore allows to limit the damage to humans as a result of a possible impact.

Active safety

The fundamental difference compared to past applications therefore lies in the fact that the possibility of contact between the machine and the worker is considered. For this reason, “active safety” is also important, even more, which includes all the functions of all the safety functions studied ad hoc and integrated into the control systems that operate thanks to the information found from the wide range of sensors these systems are equipped with. The motors, usually direct drive, are equipped with Hall effect sensors capable of measuring the rotation speed of the joints with high precision. Furthermore, the encoders installed on each rotating joint favor the redundancy of the measurement system, helping to provide safe and reliable information to the control unit. By doing so, even the basic models without integrated cameras are able to interact with the external environment by adjusting the force applied and ensuring the safety of the staff.

Security in the collaborative environment can also be enhanced through all the sensors and systems that can be integrated with the robot to adapt it to any desired operation. This category includes vision systems, lasers and other space-limiting sensors that ensure that the dangerous event does not occur. Research at the industrial level has always been interested in this type of machine control. In fact, recently the researchers' goal, with the aim of making the work environment more and more symbiotic, is to make the machine more similar to humans also from the decisional point of view, giving it the ability, not only to be aware of the surrounding environment, but also to foresee the possibility of manifestation of an event.

Finally, the goal of this thesis is first of all to show how this platform can be implemented and then integrated into the Infotainment Quality testing process. After identifying the standards for the implementation of the tests, simulations will be carried out and the related reports analyzed containing the data found so that the methodology can show whether the system is consistent and reliable or, if not, where and how it is necessary to act to make it so.

The thesis is therefore structured as follows: after a first and brief description of the robotic platform in chapter 1.

During the chapter 2, a first analysis of the methodology conducted in FCA by the specialists is carried out from which new perspectives emerge for the implementation of the platform in system testing.

Chapter 3 was instead dedicated to the description of the actual implementation of the platform in the methodology, redefined after a careful analysis of the technological capabilities and limits encountered during the comparison with the traditional "human" methodology.

In chapter 4 the actual simulation process and the data deduced from the completion of the testing process have been analyzed, which can take place in different ways and under different conditions.

On the basis of the performed activities and criticalities found during the development of the project, in chapter 5 the collaboration and support received and the contingent solutions to the problems encountered are dealt with in detail.

Finally, the last considerations, the benefits obtainable from the application and standardization of this technology and methodology, the limitations and the potential future steps for the research have been reported in chapter 6.

1 TECHNICAL DESCRIPTION OF THE ROBOT PLATFORM

The robotic platform is a machine supplied by COMAU S.p.A. called the FCA949 Mirafiori Infotainment Machine.

As for any automated instrumentation, safety requirements have been approved for what concerns the use and the resulting responsibilities; in particular, the set of established requirements includes: purpose, definitions, applicability and, so, operating procedures (-transport, installation and commissioning -manual and automatic operation -machine management -decommissioning and dismantling -maintenance and repair).

Obviously the machinery, in order to carry out its automatic functions, needs to be controlled by computer, so, in addition to the encumbrance due to the presence of the car (fixed position), the machine itself (and all the positions that it can reach) and control boxes (objects containing wiring and drives) should also be considered a space for a desk workstation equipped with a PC.

The computer is also essential for the development of the tests, starting from the programming to the drafting and finally the sending in execution; it is also necessary for the software management, both of the machine and of its application and auxiliary tools.

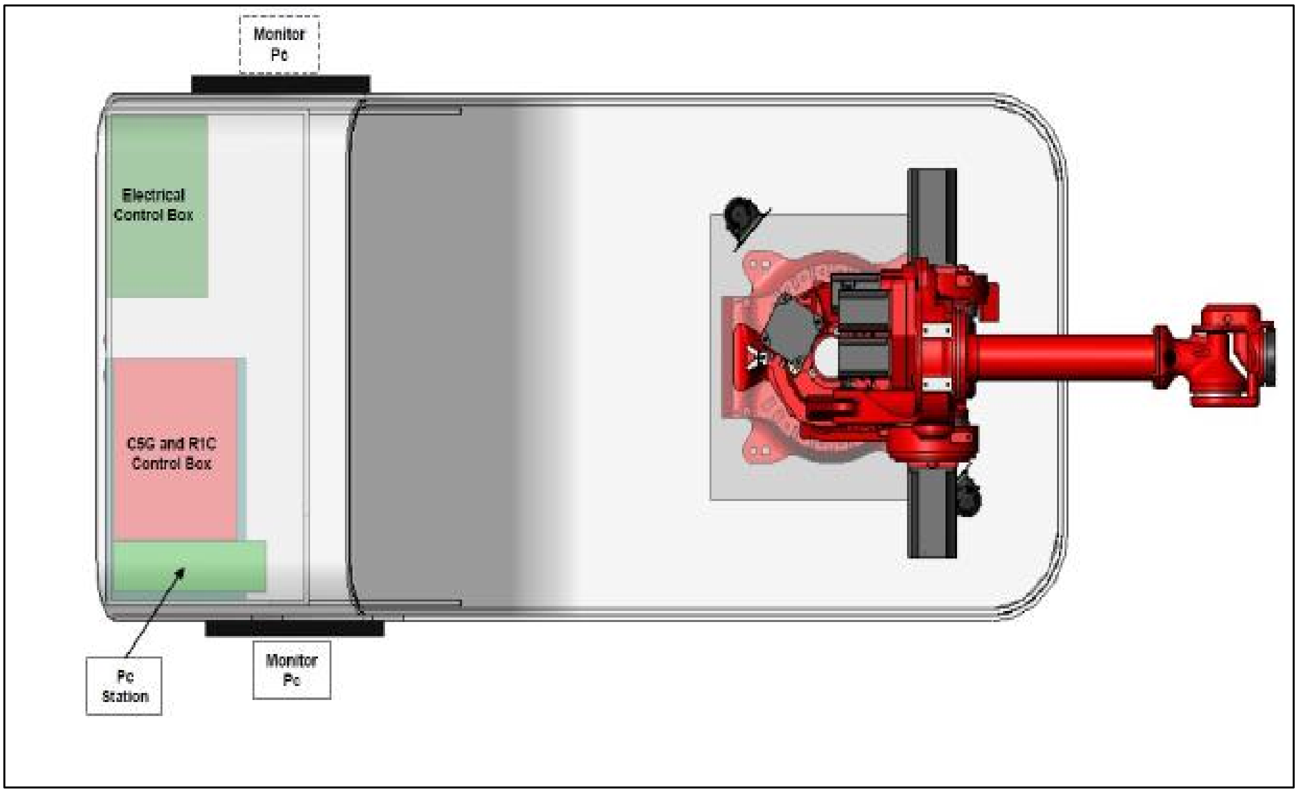


Figure 1-1 Infotainment robotic platform layout

Actually manual control is also possible via two portable push-button panels that are actually the main terminals of the machinery, each for robots, called Teach Pendant 5th generation (TP5) and in case of urgent safety reasons it is also possible to remove the power supply by using a push-button panel present on the energy disconnecting cabinet (electrical cabinet) and above the aforementioned devices.

On the pushbutton panel of the electric cabinet there are also the keys for the manual restart from an emergency situation and the general start of the machinery.

Figure 1-2 Pushbutton

There are also two other types of safety devices:

1. Laser scanners: 3 units
2. ZSM Activation device - “Deadman” device: 1 unit

The functions and use of these devices are described in the following paragraphs.

1.1. PHISICAL FRAME

The machine essentially consists of two robots and a gripper:

1. Robot 28 R1- Smart 5 NJ 130 2.6 with C5G control box
2. Robot 29 R1 - Racer 5 with R1C control box
3. Gripper Onrobot RG2

The first two are manufactured and supplied by COMAU, while the third is clearly produced by Onrobot and subsequently assembled by COMAU in the creation of the machine package.

It is evident that the complexity of the structure makes installation and calibration maneuvers difficult both because of the enormous weight and the very high level of precision required; however, thanks to the complete support provided by COMAU, both in terms of technical supply and know-how, it is possible to carry out the procedures prior to use effectively and in complete safety. In particular, as regards the calibration process, COMAU also offered a dedicated amount of hours in the training service package, with the aim of making the user of the machinery autonomous from the point of view of installing new cars. On the other hand, for personnel safety reasons, it is strongly not recommended to move robots independently from COMAU technical support.

1.1.1. BIG ROBOT

The robot 28 R1 is informally referred to as Big Robot given its large size, in fact its length in extension and weight are truly remarkable:

- extension / outreach [m] = 2.616
- mass [kg] = 1050

Which is why the extension of the floor surface and the weight tolerable by it are in the installation process fundamental and binding parameters and of which the company must absolutely consider the values before proceeding with the realization.

Figure 1-3 Robot Smart 5 NJ130

The robot is anchored and bolted to the floor and, for safety reasons, the base is equipped with a cover that holds the machine pedestal, all nearby wiring under its surface and the cabinets.

As regards the structural frame, the robot consists of 5 arms and 6 joints, each of which corresponds to an axis of rotation and, therefore, a degree of freedom; it is clear how this configuration gives a very high level of flexibility and allows you to approach and move away from the car in complete safety given the high range of movements available and the high degree of precision given by the great rigidity and stability of the system.

Figure 1-4 Control Box C5G Robot Smart

The robot is controlled in two ways: manual (programming) and automatic (remote).

The first is managed through the use of the aforementioned TP5, a multifunctional terminal device capable of not only implementing the movement of the robot, but also of programming it at the software level, starting from the safeties and the definition of spatial coordinates up to the calibrations and automatic movements.

Figure 1-5 TP5

The commands activated by the TP5 pass through the C5G Control Box network and reach the robot, activating its drives and actuators; on the device there is also a command, known in jargon as "mushroom", which allows the deactivation of the power supply (therefore connected to the energy management device), inhibiting the movement of the robot in case of extreme urgency relating to the safety of the personnel or the car.

The second way is implemented through the use of the workstation PC and one the three software related to the use of the machine: the software is therefore able to send and receive signals in/from the network of the Control Box C5G and of the robot.

Three further safety devices are present: laser scanners that cover the entire surface (radial laser beams adjustable during the safety phase through a specific software configuration) around the 28R1 and the car itself, capable of immediately stopping the movement of the robot if any physical access to the area is detected.

Figure 1-6 Laser scanner

Two of these are positioned on the cover near the Big Robot base and essentially identify the space in which the machine (in particular the Big Robot) can potentially impact a person. The triggering of the laser scanner 1 blocks the Big and is neutral towards the Small while the laser scanner 2 blocks the Big and activates the low speed of the Small.

Figure 1-7 Laser scanner 1 - 2

The third is instead positioned near the car to be tested and has the task of detecting the possible transition of the operator on the car from the passenger side.

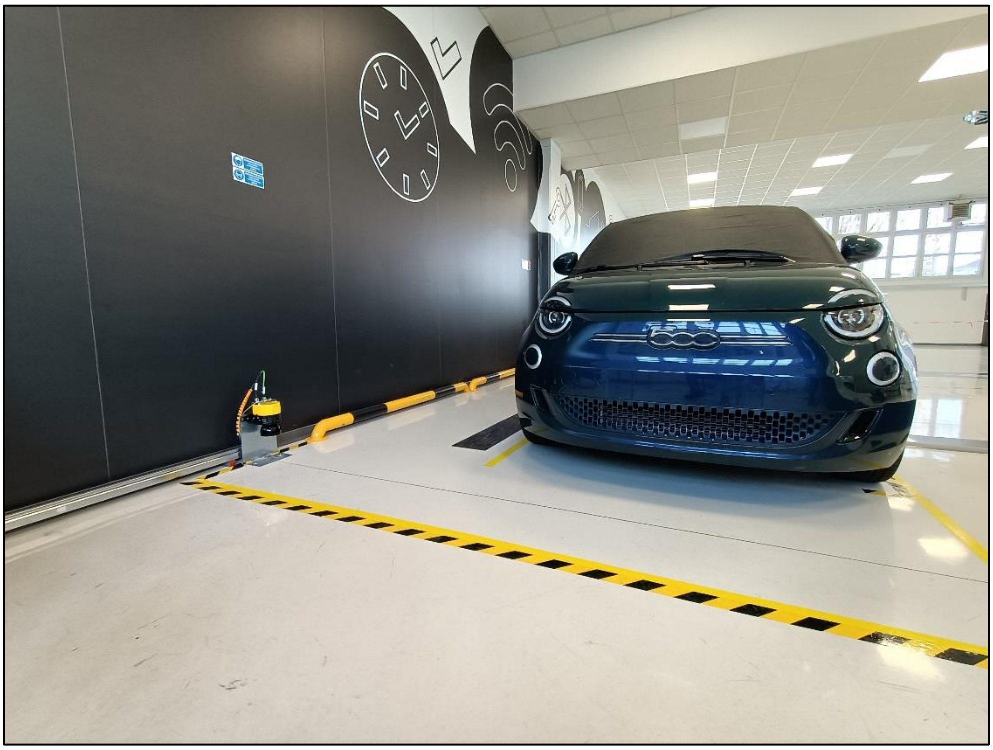


Figure 1-8 Laser scanner 3

In addition, the configuration of the laser scanner areas includes 4 switch modes relating to the type of vehicle to be tested: compacts, sedans, SUVs and LCVs; it is possible to switch on the HMI PLC (which will be discussed later).

Big Robot	
Model	Smart 5 NJ 130 2.7
D.O.F **Degree of freedom**	6
Payload [kg]	130
Repeatability [mm]	0.07
Outreach [mm]	2616
Weight [kg]	1050

Table 1 Big Robot technical characteristics

1.1.2. SMALL ROBOT

The 29R1 Racer 5 cobot is nicknamed Small Robot due to its considerably smaller dimensions than the Big one and for the possibility of getting into the car and moving inside it, clearly provided that the programmed movements keep in consideration of the dimensions of the body interior avoiding contact with the components of the latter.

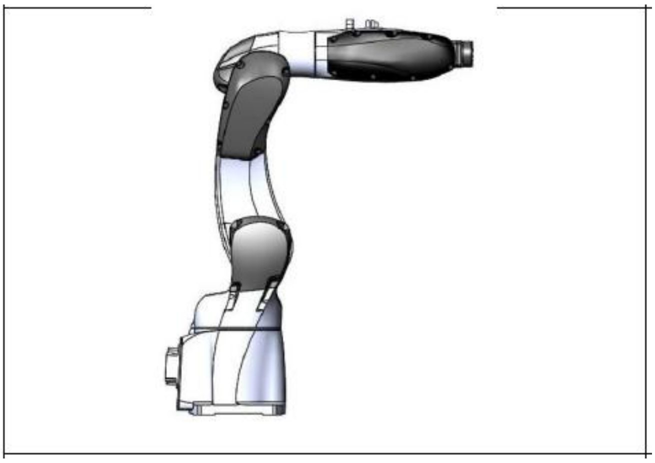


Figure 1-9 Robot Racer 5

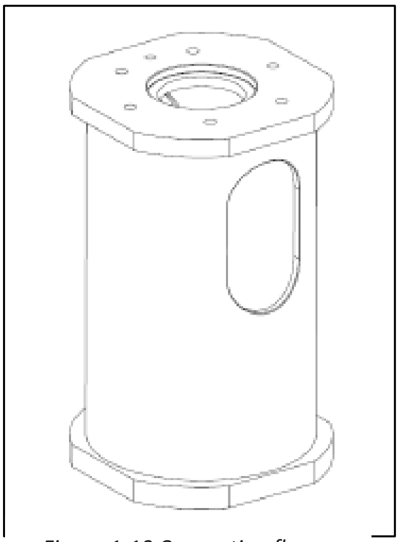


Figure 1-10 Connection flange

The Small robot is fixed on arm 5, more appropriately defined wrist of the Big robot, through the use of a structural flange perforated at both ends to allow coupling and on the side walls to allow the passage of the drive cables.

The Racer 5 cobot is an "intrinsically" safe *cobot*, that is, it moves at low speeds and is extremely sensitive in the sense that it only needs to be touched, with a certain intensity, to stop. When a collision with an external body occurs, the resisting torque, detected by the robot and processed by the control units, rises and a higher current intensity is required for the drives and once a threshold defined in the design phase and stored in validation is reached, the machine stops. It is, therefore, a machine able to detect the collision and send back a signal to its Control Box which processes it very quickly for its priority and sends a stop signal to the whole system, including therefore also the 28R1.

The Small robot is also structurally framed in 5 arms and 6 joints and axes (6 d.o.f); it is also a system no less rigid and stable than the Big one by order of magnitude, thus allowing very precise handling, also due to the lower speed of the movements.

Figure 1-11 OnRobot RG2 Gripper - Onrobot

The OnRobot RG2 Gripper is mounted on the wrist of the 29R1; this is an end effector, a collaborative gripper which allows the robot to carry out the operations of activating the Infotainment system. At the ends of the instrument there are two rubber shims that reduce the pressure of the contact of the machine on the screen and the useful instrumentation on the dashboard and steering wheel (i.e. keys and buttons). The gripper is functionally connected to the 29R1 via an I/O converter.

OnRobot	
Model	RG2
Payload [kg]	5
Repeatability [mm]	0.1
Outreach [mm]	110
Weight [kg]	0.78

Table 2 OnRobot RG2 technical characteristics

On the wrist of the Racer 5 there are also:

- DALS Vision Camera Genie Nano - Teledyne, connected to control devices via Ethernet cable, for viewing and checking the tests performed on the Infotainment system. It is integrated with a vision system management software provided by Halcon.
- Speak 410 USB Speakerphone - Jabra, connected to the control devices via USB, for carrying out audio tests on the Infotainment system.

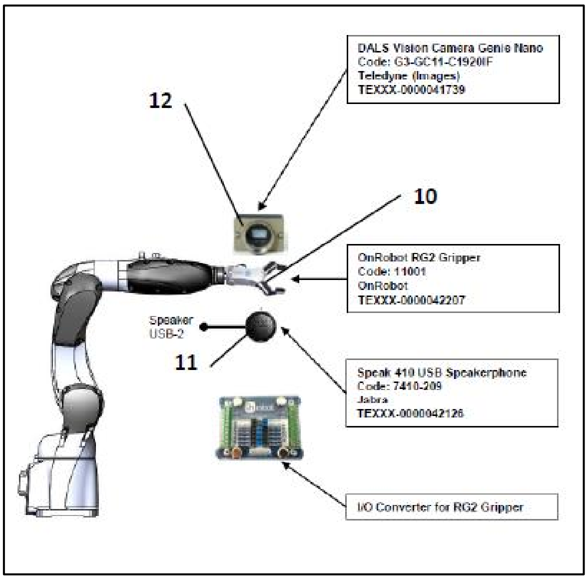


Figure 1-12 Wrist robot Racer5 Composition

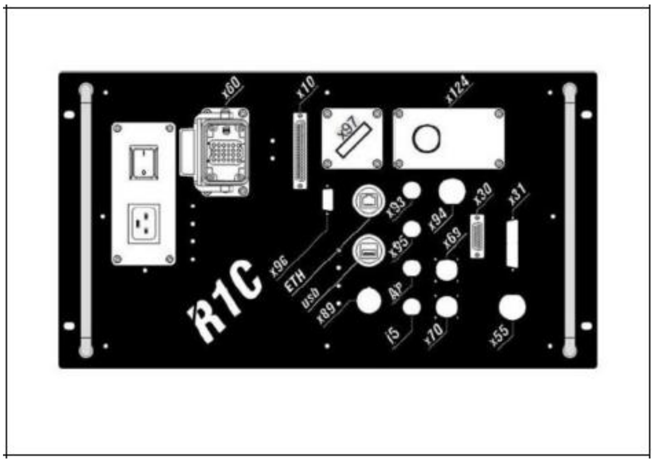


Figure 1-13 Control Box R1C Robot Racer

Like the 28R1, the Racer5 is also controlled in two modes, manual and automatic.

Also in this case for the manual mode a TP5 is used which is practically identical to the previous one for functions and applications; obviously in this case the TP5 is connected to the Control Box R1C Robot Racer.

As for the automatic control, the information given in relation to the Big robot is also valid for the Small one.

The use of the ZSM Deadman device allows the implementation of additional safety functions for the application, in relation to the position of the operator while moving the Small robot in the car, this last one moves at two different speeds:

1. Collaborative (50 mm/s) : when the third laser scanner detects the operator near the car on the passenger side (on PLC HMI the "Safety Low Speed Active" icon lights up);
2. Standard (300 mm/s): when the operator is outside the detection area of the third laser scanner OR when the operator is in that area but holds the Deadman device (on the HMI PLC the "ZSM Active" icon lights up).

Figure 1-14 ZSM activation device

Small Robot	
Model	Racer 5 cobot
D.O.F Degree of freedom	6
Payload [kg]	5
Repeatability [mm]	0.03
Outreach [mm]	809
Weight [kg]	32

Table 3 Small Robot technical characteristics

Type	Traditional Industrial Robot	Collaborative Robot
Safety	Potentially harmful, it requires protection	Designed to be safe
Work with man	Not allowed, requires barriers	Possible with due consideration and precautions
Difficulty in programming	High	Contained
Payload	High	Reduced
Outreach	Long	Limited
Speed	High	Limited
Adaptability	Low: great for large volumes and limited processes	High: Great for small volumes and heterogeneous processes
Price	High	Reduced

Table 4 Main differences between cobots and traditional robots

1.2. FUNCTIONALITY

The most interesting aspect of the robotic platform certainly concerns its functionality and the consequent applications deriving from it. The development and experimentation in the use of the machine have made it a real engineering jewel in terms of automation, consistency, robustness and, moreover also machine learning, thus interfacing in the world of Artificial Intelligence (ie AI) aimed at the industrial world, implementing the modern concepts of Industry 4.0.

Clearly, given the value and cost of the equipment, although the functions are quite simple and intuitive in their execution, it is necessary that the conductor, that is a member of the designated staff authorized to work near the robots by the company's Safety-Prevention-Protection Manager (aka SPPM, in Italian RSPP), is qualified and therefore able to perform:

- running the station using the commands on the TP5 and on the video terminal through the software
- simple adjustment and start-up functions
- the restoration of the cycle following a forced stop

A first introduction are aimed at fully understanding the instrumentation in use starting from the Electrical Control Box cabinet (or energy selector) and the power supplies derived from it, both 230 Vac (among which it is important to detect the presence of the Webcam, which will be discussed later) and 400 Vac, focusing particularly on the functions of the push-button panel placed on it. Another very important aspect described in the introduction certainly concerns the video pages on the terminal and their management, we therefore speak of the HMI (i.e. Human Machine Interface) or operator panel: the video pages are shown on the PC monitor through the SIEMENS SIMATIC interface sw WinCC Runtime Advanced 8192 PowerTags V15.1. HMI is used to position robots in various testing operations.

Then we have a crucial point, the calibration that is the most technically complex operation and therefore require particular attention to fully acquire the management faculty. The COMAU Dexterity software is used to perform the calibration operations, which is described below; inside the software interface there is a TAB dedicated to the aforementioned operations, and calibration plates (or markers) are also supplied, that is to say stickers with a distinctive pattern which directs the robot through recognition via the camera and the algorithm of the software vision system.

Then it is necessary to deepen the concepts on use of the editor area of the Dexterity sw, paying particular attention to the understanding of the metalanguage, that is *a "language" above the programming language that define in a formal and unambiguous way the set of syntactic rules of that specific programming language*; in this case the metalanguage has the function of making readable both to the average user, who may not have advanced computer knowledge, and to the machine, the actions that the latter must perform. The "sum" of the actions composes the test cases whose "sum", in turn, generates the test sequences.

The next step includes learning how to carry out test cases and sequences through the TAB Test Player.

The final functions are based on understanding logging and reporting through Veristand and the sw DIAdem basics by National Instruments. The logging and the reports are obviously the output of the entire test and are therefore the synthesis of the process.

1.2.1. SOFTWARE

As previously described, there are three software for the management of the robotic platform and the execution of the tests:

1. WinCC Runtime Advanced 8192 PowerTags V15.1 by SIEMENS SIMATIC (PLC HMI)
2. Dexterity by COMAU
3. DIAdem basics by NATIONAL INSTRUMENTS

Figure 1-15 Siemens Simatic logo

Figure 1-16 National Instruments logo

Figure 1-17 Comau logo

1. This software therefore interfaces with the machine and allows you to control its trajectories, carry out diagnostics and manage any anomalies: this is installed on PLC (programmable logic controller, *it is a digital computer used for industrial automation to automate different electro-mechanical processes*)

   The main page of the HMI of PLC is divided by type of command:

   - off-vehicle commands, i.e. REST, ARMING PREPARATION, ARMING CHECK
   - in-vehicle commands, i.e. STAND BY, EXIT, OUT OF CLEARANCE
   - general commands (to reset errors and start the cycle, to move manually or automatically)

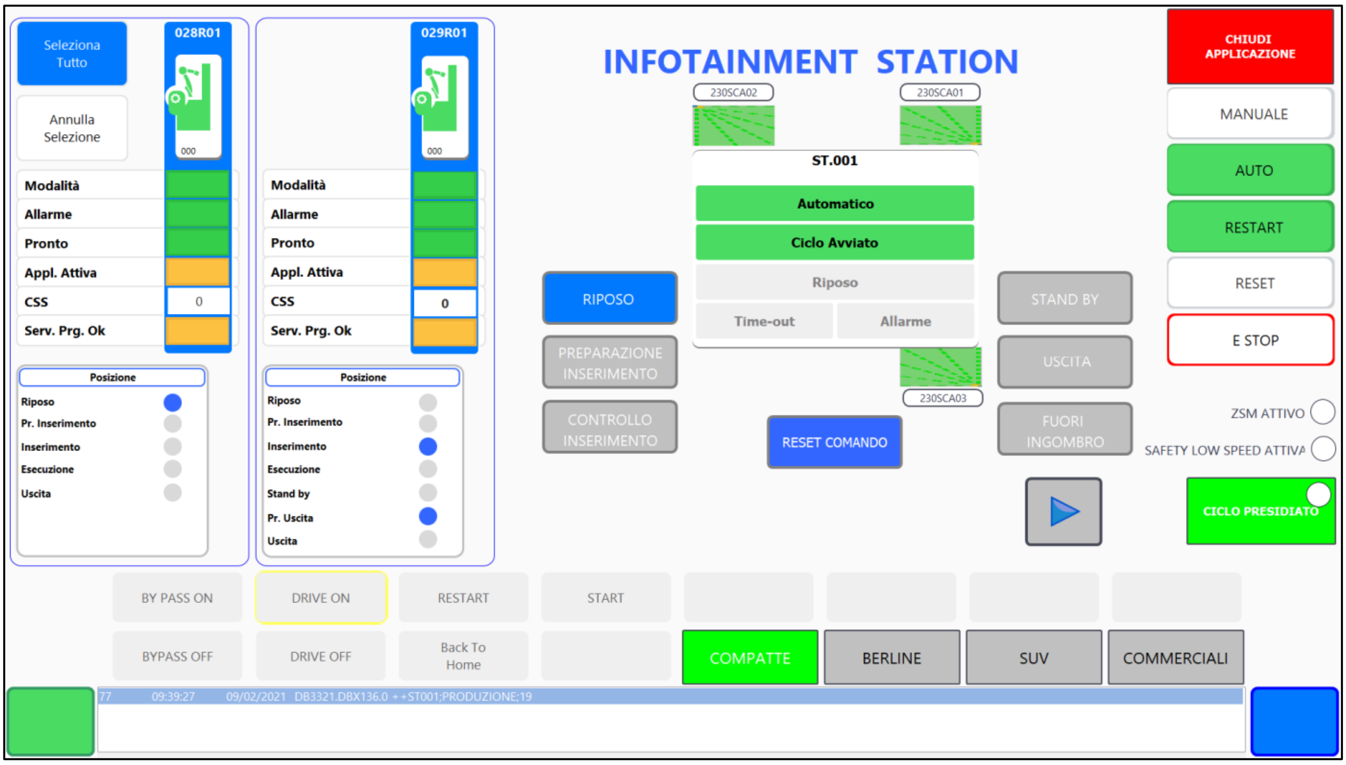


Figure 1-18 HMI main page

In the REST position, the Small robot is in a position that allows the operator to move in and around the car.

Figure 1-19 REST

From this position it is possible to start the cycle once any errors have been eliminated and after having pressed RESET and COMMAND RESET, then RESTART is pressed, the machine therefore works automatically, i.e. in the mode designated for carrying out the tests.

Then press the ARMING PREPARATION, ARMING CONTROL, very important because it identifies the position through which the small robot enters in the car, and STAND BY keys in succession, where the robot is placed in the car and is ready to perform the actions.

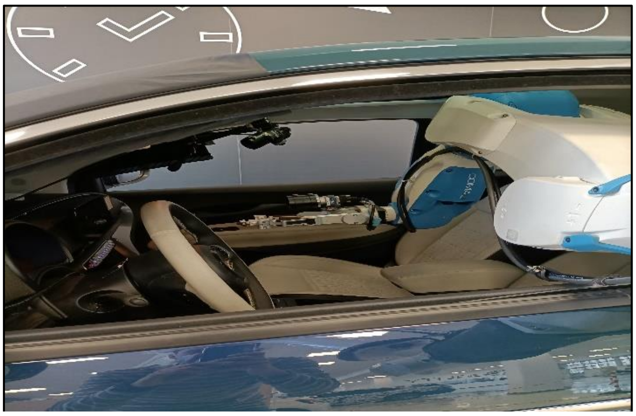


Figure 1-20 STAND BY

The FORWARD command is used to put the robot in communication with the Dexterity sw.

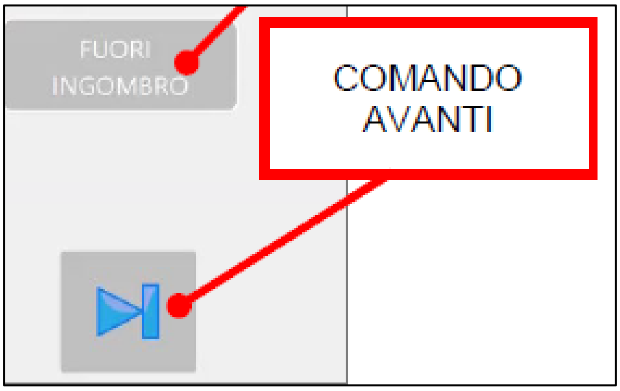


Figure 1-21 FORWARD command

The succession of the EXIT and OUT OF CLEARANCE commands allows the Racer 5 robot to exit the cockpit and put it into a safety position for any operations in the car.

From the OUT OF ENCLOSURE position it is possible to return to the REST position by pressing the command.

2. The Dexterity sw is the real focal point of the robotic platform. It is used to perform the robot configuration and calibration, then test execution operations sequentially inside the car; during the test the software acquires data, generates a video via the webcam and traces the whole process of the test sequence, information which is then sent to DIAdem basics.

   The main menu consists of 4 TABs:

   - configuration
   - calibration
   - test editor
   - test player

   The main configurations are carried out in TAB configuration: Test Sequence selection (load/edit), Robot (Big / Small) IP address and port, Camera (Static / On board) serial number, NI Veristand with system definition file and stimulus profile file, Calibration file, Components active inside the system (Robots and OB Camera that are essential for the execution of tests, Static Camera, Veristand, AI Engine for speech, sound and keyboard), Deploy command for test execution.

Figure 1-22 TAB configuration - Dexterity

Through the TAB calibration, the calibration operations are carried out starting from already prepared files or generating new ones; the calibration is a procedure through which a robot is able to locate completely itself inside the space, using a vision system and a calibration plate; this can be done by extracting homogeneous matrices between relevant points in the scene. Thus, certain parameters being known, i.e. the transformation matrix between the wrist of the Small robot and the base of the Big robot and that between the camera and the calibration plate applied to a certain reference point of the test object (the Halcon software is able, thanks to the intrinsic configuration of the cam, to numerically extrapolate the coordinates) you can proceed to the system resolution: it is still necessary to find the transformation matrix between the camera and the wrist

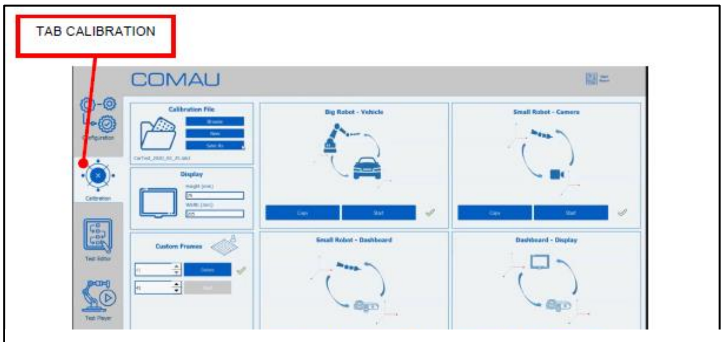


Figure 1-23 TAB calibration

of the Small robot and the one between the base of the Big robot and the test object. For the first it is sufficient to perform a series of pictures of the calibration plate in the scene, knowing the corresponding wrist poses (in the base frame) of the Big robot and intrinsic camera parameters, for the second it is necessary to perform the matrix calculation in the correct way according to the reference frame and close the kinematic chain. The starting point for a calibration in a new vehicle are the dimensions of the Infotainment display and the positioning of markers and custom frames (precise reference points inside the vehicle), subsequently for both the Big and the Small robots a standard procedure is followed which, through the recognition of the markers, allows the correct calibration. All calibrations inside the vehicle refer to the STAND BY position.

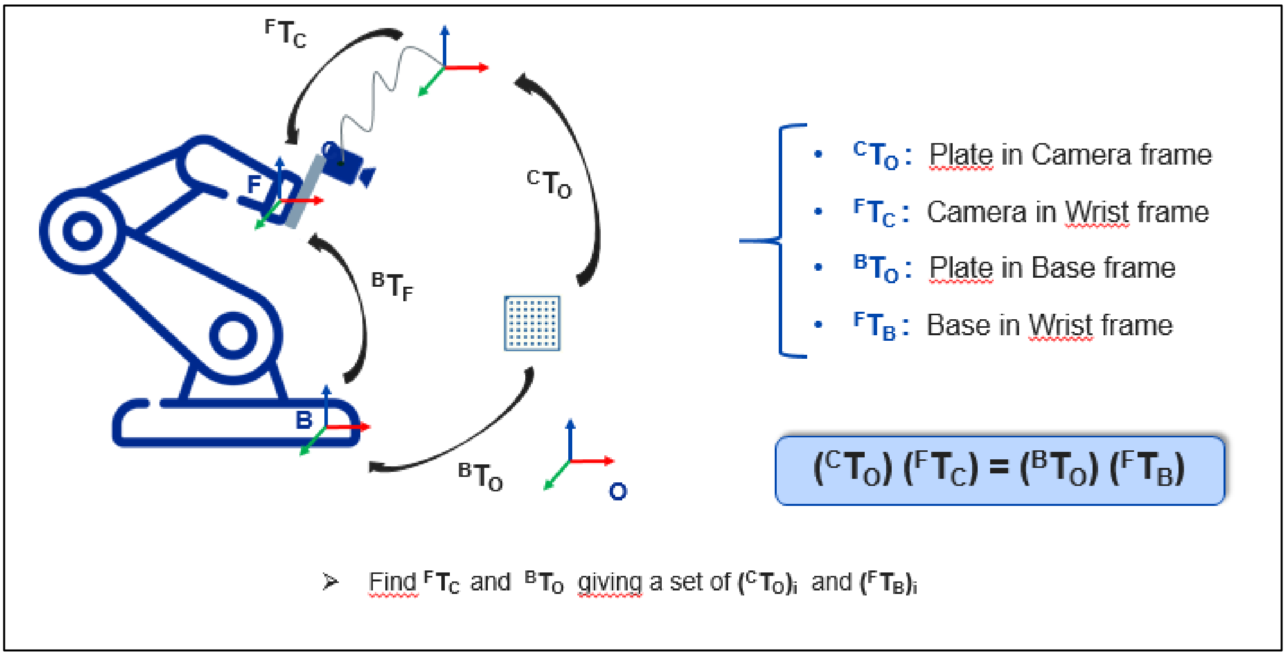


Figure 1-24 Transformation matrixes - Calibration

Test cases are created in the Test Editor. The table on the left contains the schematized and indexed test actions, each row corresponds to an index that defines the sequential order of the actions; moreover, each action has a standardized description with the following logic: ID - Condition - Action - Type - Arg1 - Arg2. Each of these items corresponds to a column. The Condition is used to create cycles or to set binding conditions. In relation to the selected Action, one or a list of Types corresponds. Arg1 specifies the content of the action, while Arg2 imposes conditions on the content of Arg1, e.g. offsets, iterations, search direction. To the right of the table there is the Add Test Action section through which the desired actions can be entered in a simplified mode. Below the table there is the CSV file loading button, that is the format that the sw converts into actions for the machine, the total cleaning button of the table, the save button of the current file and the error section in compilation.

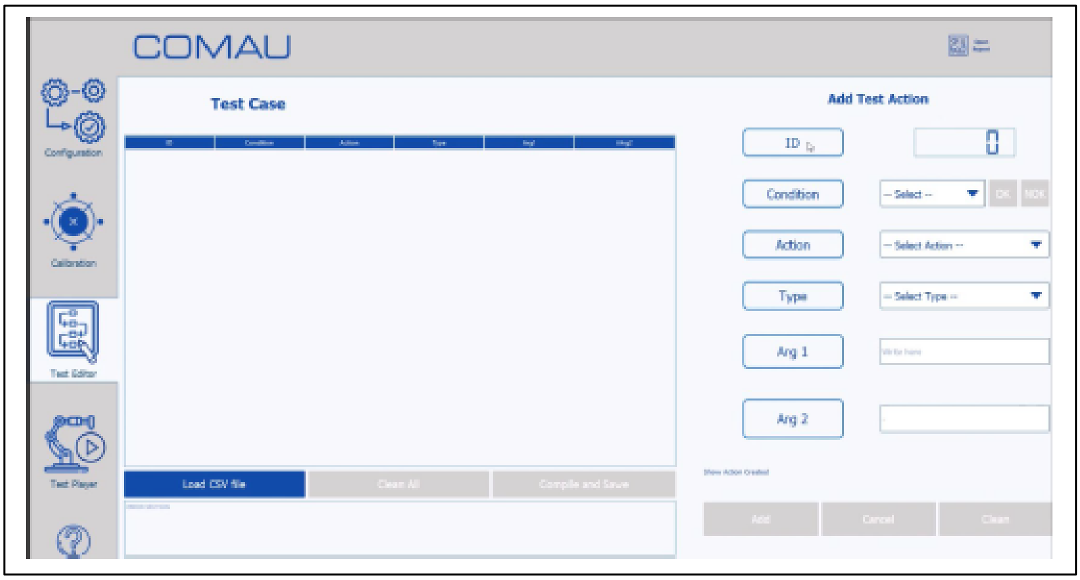


Figure 1-25 TAB test editor

Through the TAB Test Player it is possible to view the main information coming out of the live test execution, including videos and images captured by the two cameras. The tab is divided into four sections:

- the first, top left, shows the images captured by the camera on board robot;
- in the second, top right, the video of the execution generated by the static camera is projected
- in the third, bottom left, the sequence of actions is shown with the relevant information
- the fourth, at the bottom right, shows the service information

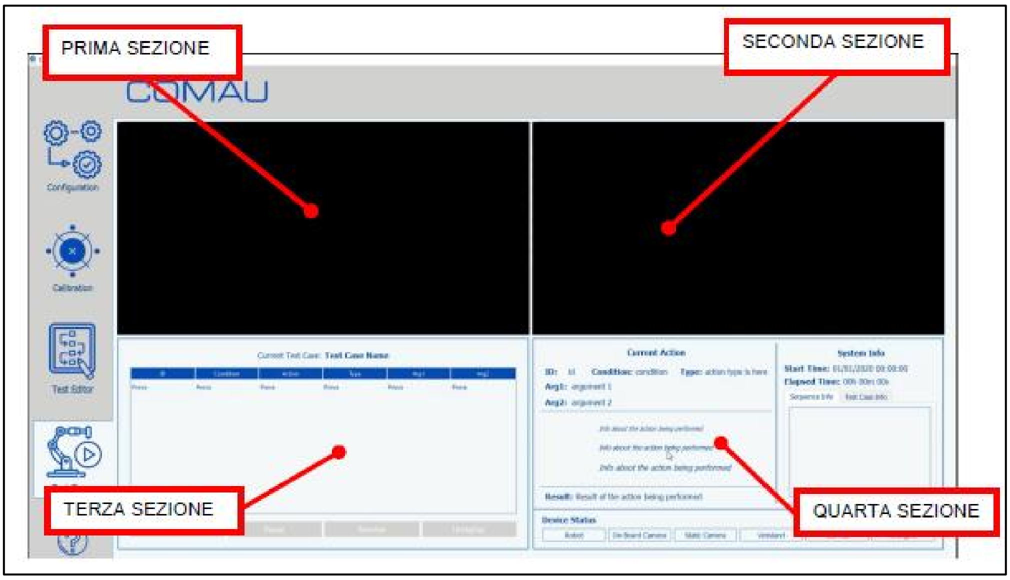


Figure 1-26 TAB test playe

3. By means of the shortcuts present on the Dexterity sw it is possible to interface with the DIAdem basic sw, which is the reporting container.

   This sw allows the examination of the test frame by frame, giving information both on the service, useful for debugging and development of the platform by the manufacturers, and to the user in terms of signals coming from the CAN network that can be deduced and analyzed *a posteriori* in support video information, generally more superficial. It is therefore a real logging of the network and its communication system, an essential aspect in managing the problems encountered.

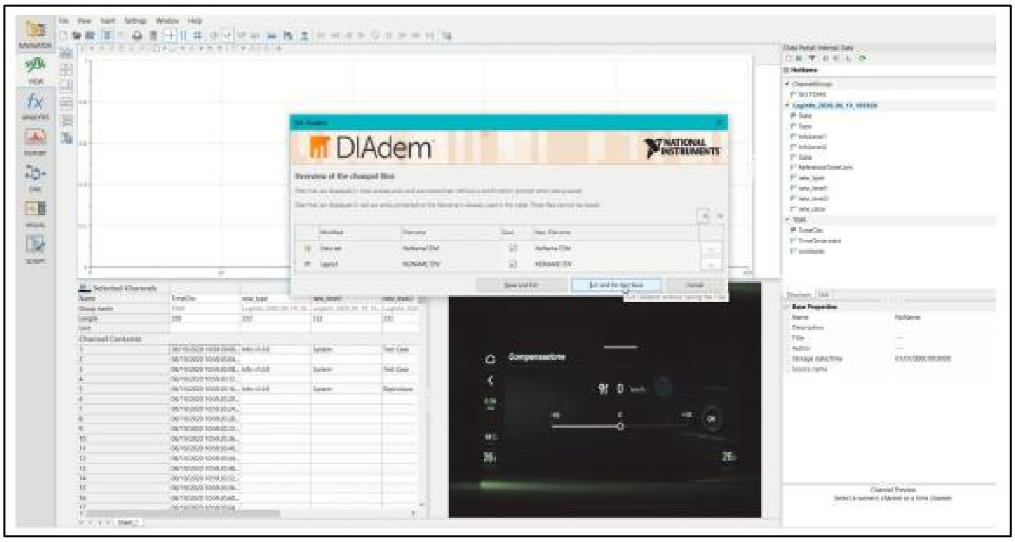


Figure 1-27 DIAdem basic

- Integration of .tdms files, to analyze and inspect data coming from log acquisition with Veristand
- Analyze any kind of text file formatted in different ways, which is useful for opening the Master Log file
- Projecting video and pictures
- Complex graphical instruments for showing report in user friendly way
- Synchronization of different items inside a report
- Custom generation of signals for integrating and completing the imported data structures

1.2.2. APPLICATIONS

The assembly of such a complex hardware with three management software leads to the creation of the robotic platform to which only the object on which it works remains to be added: the car with the Infotainment system inside. The platform is designed and built to be flexible to the type of vehicle tested and to be influenced by it in the least possible intensity: this is why the machine has been built in two macro physical components capable of freeing their actions from the boundary conditions of the test, on the other hand, giving enormous weight to the conditions of service, configuration and calibration; in short, the tested object is not a constraint to the extent that the configuration and calibration process performed upstream is carried out correctly by expert hands.

To carry out these preliminary operations well, it is necessary, in addition to knowing how to correctly manage the HMI and Dexterity sw, also knowing how to correctly juggle the TP5 device for manual handling and programming of movements. In fact, as described in the previous paragraph, the learning hours spent on these processes are the most important in the training of a user who can become independent; a basic knowledge of the concepts of applied robotics is essential in the long-term management of the platform.

Having made this necessary premise, it is possible to analyze the various applications that the platform allows:

The robot is able to perform physical pressure actions, through the ends of the RG2 Gripper, on the entire dashboard in the vehicle, in particular on the Infotainment system screen, but also on the ON / OFF key button, on the climate control panel and, in some cases, where spaces and the overall dimensions inside the frontal passenger compartment allow this, even on the buttons located on the front surface (to the driver) of the steering wheel.

Clearly the pressure of certain points in space must be programmed and programming takes place in two steps:

- a first phase in which the main movements of the entire machine are defined when approaching certain points of predefined surfaces, an operation that takes place during calibration, therefore mainly with the use of manual mode with TP5
- a second phase performed in automatic mode, then with the HMI started and set so that both robots are in automatic mode and in operation (DRIVE ON mode), and with the use of the Dexterity software and its functions.

For the recognition of the testable contents, but also for the management of the calibration process, the onboard camera and the vision system of the Dexterity sw are used.

The main applications of the platform find form in the Dexterity test editor where the user can draw up the list of test actions. The actions referred to in the sw and which are implemented by the machine are the following:

- Look: through this action, through the systematic use of the onboard camera, the robot detects the presence on the screen of images (type: image), text strings (type: text), screen in stand by (type: blackscreen), keyboard, saved and preconfigured (type: keyboard). It is certainly the most innovative action as it uses a very current technology such as the artificial vision system and the exploitation of artificial neural networks; speaking of AI applications, it is in this action that the concept takes substance and machine learning and the evolution towards digital technologies and Industry 4.0 take place, it is here that the robot assumes its autonomy and intelligence. each type of these actions has an interesting conceptual foundation but in this case it is convenient to explain their practicality: look image and look text return as a parameter the coordinate of a point (the center of the image or of the recognized text string), look blackscreen if detects the presence of a screen in stand by returns the Execution OK parameter, look keyboard is certainly the most complex type in execution as it detects the presence of a saved and preconfigured keyboard (the store path is indicated in Arg1) and, subsequently , allows you to use it to write a string of characters (in Arg2 the content is defined) that the robot itself composes. An aspect that should be emphasized lies in the algorithms that distinguish both the look image (pattern matching) and the look text (OCR "optical character recognition"): these, despite having basic differences, are the simplifying and catalysts of the vision system and, therefore, of the entire operating model of the robotic platform.

Figure 1-28 Look logo

- Listen: through this action the system recognizes and defines a sound (or a non-sound, therefore "silence") detected by the supplied microphone during the test. Also in this case, like the previous one, the system carries out an AI application through an advanced voice recognition system. There are three types of action: listen-sound through which the system returns the indication of the sound heard (returns "silence" as an alternative), listen-silence returns true or false based on whether silence is detected or not, listen-voice in which, by specifying the content in Arg1, the system must recognize whether or not the infotainment has pronounced the sounds inside it.

Figure 1-29 Listen logo

- Go to: this action allows you to manage the test sequence allowing you to return to a specific row (type line, in Arg1 the desired row, in Arg2 how many cyclic iterations you intend to perform) or to interrupt the execution of the test (type return, type undeploy) by determining also failure (type fail) or success (type pass).

Figure 1-30 Go_to logo

- Reproduce: by exploiting the use of the onboard microphone, the system is able to reproduce sounds or words indicated by the user. Reproduce voice uses the technology of *text to speech*, reproduces files and records emit sounds recorded on a file, the difference between the two types is that the latter allows you to record an audio file run in time.

Figure 1-31 Reproduce logo

- Move: this action allows you to simulate the use of infotainment by a user. In fact the robot through the gripper performs the pressure actions previously discussed, moreover the move allows to configure the simulation towards well-defined boundary conditions through the alignment on selected frames. There are therefore the following types: touch, keep pressed and swipe (up, down, left, right) which need a predefined point to act on, align which has been defined above, program that allows you to run a robot program preloaded on the memory of the robot itself. As regards the first three types, it is possible to choose an offset on the surface (with distances in mm) and for the swipes it is also possible to decide the length of the movement.

Figure 1-32 Move logo

- Veristand: its purpose is to activate the management of the CAN network in a precise moment of the test; type Modify channel value allows ………… , while type Run sequence …………..

Figure 1-33 Veristand logo

- Wait: allows you to put the machine in a rest state; type seconds requires in Arg1 the amount of seconds to wait, type sleep instead requires manual re-activation of the sequence.

Figure 1-34 Wait logo

- Execute: it is used to recall a test case in csv format previously saved; in Arg1 the complete path of the file must be indicated.

Figure 1-35 Execute logo

- Compare: this action allows you to compare two images (type image) or two text strings (type text). The algorithm used in this is matscore.

Figure 1-36 Compare logo

- Store: allows you to save a file in png or jpg format. In Arg1 you associate the ID of the action from which you want to get the image to save, in Arg2 you have instead path, offset and size.

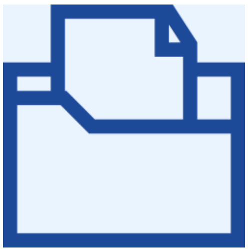


Figure 1-37 Store logo

By putting these actions in sequence, the test case is composed, which are in turn sequenced to create the test sequences, as similar as possible to the customer use and which therefore cause the platform to simulate the behavior of the customer user. Through the test player, the user of the platform monitors the conduct of the test for safety and functional reasons, as well as to obtain the reports necessary for analyzing the simulation.

2 FCA METHODOLOGY OF INFOTAINMENT SYSTEM TESTING

This chapter is fundamental to understand how we can translate a typical humankind of process in an artificially conducted one, because only having a deeply knowledge of the matter in question is possible acting on a more sophisticated system.

2.1. KIND OF PRODUCT TESTED

The first and very important point is surely the object that is tested: in such a large company, the car portfolio is much extended so one crucial instance is to find a way to test efficiently all the new product, whether they are restyling of previous or new cars at all. In fact, not all vehicles are tested: certainly, when a new car is produced, it needs to follow an entire test process, not only as regards the infotainment system; on the other hand, the restyling of a previously produced car does not necessarily have changes to the system, however, probably the integration of the system into the vehicle body may have undergone some changes and, at this point, testing becomes a process necessary to verify the system with new parameters and boundary conditions. Testing is the most important concern of Reliability

The other macro factor to consider is obviously the supply of the same infotainment system: each company is inserted in a competitive and/or cooperative context and follows its own business logic, its strategy, in order to pursue a predetermined number of objectives, in terms of brand image, added value, product quality, investments, costs, lessons and know-how learning and this could go on indefinitely. In order to pursue its goals, a very important aspect is in the choice of suppliers and in the way of approaching, negotiating, defining terms, developing, producing, verifying and controlling with the latter ones.

Therefore the choice of suppliers and the products they offer becomes another fundamental parameter and strategic factor in the testing and reliability process, both as regards the implementation of the process itself and for the aspect of verification and management of the problems that arise during the process.

2.1.1. VEHICLE

Although the group to which it belongs today is Stellantis, the project was carried out in its entirety under FCA governance and it is therefore more correct to mention the latter for what concerns the reference to the company where the project itself took place.

First of all, a cataloging of the testable vehicles must be carried out and, as previously mentioned, the cars to be tested are essentially of two types: new products or restyling of old ones.

FCA is, as everyone knows, a company that incorporates within itself a variety of brands also coming from very different contexts, for example Jeep and Chrysler are US brands while FIAT and Alfa Romeo are Italian. It follows that, in order to operate efficiently, it is necessary to try to standardize not only components and systems that are assembled to make up the vehicle, but also processes and *modus operandi* that must be assimilated and practiced in a consistent and effective way in all the factories around the world of the company.

Figure 2-1 FCA brands

Consequently, the way to test the cars becomes a standard for the factory: regardless of the brand, the product line and the components and systems of the product, a procedure is identified that is carried out; first of all, for each product line, two qualified macro-categories are distinguished according to the level of progress of the project status as regards the pre-production phase, we have vehicles as follows:

1) Validation process, initials VP

   The vehicles that are in the validation process state are characterized by the fact that they are still prototypes and therefore subject to possible modifications following technical and performance checks on systems and components, in particular in terms of process and are classified as OFF TOOLS vehicles since the making of these cars completes the tooling development process, with the making of the molds and the final production equipment; the first checks of design validation are completed so giving the start of the bodywork ("*lastratura*"). Through these cars the first RG durability loop is performed.

2) Pre series, initials PS

   The vehicles that are in the pre-series state are vehicles produced at the end of the process verification in the production readiness process, with a significance level close to 100%, so much so that some models of the lot are even marketable (*Fast Feedback* vehicles or *Internal Customer Fleet*) and therefore not anymore subject to macroscopic modifications; they are classified as OFF TOOLS and OFF PROCESS vehicles. Through these cars, the second loop of RG durability is performed and the Production Release Approval and Job1 are obtained (first car produced in series production).

In terms of quality at an industrial level, it should be specified that the significance of a product indicates a percentage measure of how close the product itself is at present to the specifications required in the final state.

It is worth remembering that the cars produced immediately after Job1 are named with the acronym IP ("*Inizio Produzione*" that is Production Start), they are intended for the final customer and a small batch of these it is tested in RG for the final validation of the product.

For the entire duration of the internship experience, over the period between August 2020 and February 2021, the only car taken into consideration for testing with the new robotic platform was the new Cinquecento BEV (Battery Electric Vehicle), project 332, which has recently entered the production line and marketed. Clearly this was not the only model tested in Infotainment at Mirafiori in the aforementioned period, as other products, such as the new Maserati models to name a few, were also subject to checks.

In particular, the cars in question were two: the VP 107, from August to December and the PS 60, from January to February, two cars from the RG fleet that reached the end of its accumulation (of km) and which were entrusted in those periods to the exclusive use of the platform; clearly during the entire duration of their use, the cars were provided with all the software updates necessary to make it a significant object for real testing purposes. In particular, the transition from VP 107 to PS 60 was desired due to the need to test a model with Infotainment in a PROD environment (the VP 107 had a PRE PROD environment instead), therefore more significant in terms of marketing.

Figure 2-2 500 Cinquecento BEV

Another fact is that the first installation and calibration of the robots was carried out on an Alfa Romeo Stelvio. The main difference between the two cars in the robotic application lies in the fact that in the second, the Stelvio, it was possible to move inside the passenger compartment with greater freedom, so much so that accessibility to the steering wheel buttons and the IPC view (Instrument Panel Cluster) was guaranteed.

Figure 2-3 Alfa Romeo Stelvio

It is well known that the new course of the automotive world is turning towards massive electrification and more and more embedded electronics and mechanic systems, so FCA corporate is also facing this process, which is so important for the future scenarios of the aforementioned industry and beyond. In the case of product Quality and Reliability, therefore in the RG tests a whole series of changes are applied not only on the type of product tested, therefore electric or hybrid vehicle, but also on the methods to be followed during the test indicated by a new internal regulation, 7.T4063, "special reliability tests and tests from a customer perspective of hybrid and electric vehicles", which is integrated with 7.T4051, "reliability growth testing".

In the first paragraphs of the 7.T4063 standard the test equipment and instrumentation are specified, of which the CAN-Case (also known as data logger or acquirer) suitable for reading and extrapolating the data of all the vehicle CAN networks is of interest for the relationship with the infotainment system and others embedded system. The rest of the standard also as regards the 7.T4051, deals with the methods of conducting the tests and the status in the accumulation cycles of the cars of the reliability batches.

2.1.2. INFOTAINMENT SYSTEM SUPPLIER

The other big macro factor is absolutely the type of hardware and software of the infotainment system supplied. Clearly, each supplier develops its own product based on its own needs, possibilities and objectives and, consequently, the characteristics of these are essentially different in two respects:

1) first of all, the hardware of the individual systems is different; each system has its own geometric dimensions (volumes and surfaces) as regards the casing, its own geometry of the internal circuits and a different integration to the vehicle's electrical-electronic system. Clearly all this is then to be correlated to the different types of vehicles on which they are installed.
2) secondly, each system has its own integrated software and this strongly affects both the communication methods that the vehicle has towards it and the effective control of the system by the user and the monitoring that the supplier is able to provide in towards the company during all stages of development and, subsequently, in the commercialization and circulation of vehicles.

2.1.2.1 EXCURSUS ON SOFTWARE VALIDATION

Precisely regarding the software validation topic of the test object, it is necessary to deepen its details: software testing (also called testing or software testing) indicates a procedure, which is part of the software life cycle, used to identify the deficiencies of correctness, completeness and reliability of the software components in progress of development. It consists in the execution of the software by the tester, alone or in combination with other service software, and in evaluating whether the behavior of the software complies with the requirements.

The purpose of the test is to detect defects through malfunctions, in order to minimize the probability that the distributed software has malfunctions in normal operation; no test can reduce this probability to zero, as the possible combinations of valid input values are enormous, and cannot be reproduced in a reasonable time; however good testing can make the probability of failure low enough to be acceptable to the user. The acceptability of a given probability of failure depends on the type of application.

The verification and validation phase serves to ascertain that the software reflects the requirements and that it respects them properly. Precisely, the verification serves to establish that the software complies with the requirements and specifications, so for example that there are no missing requirements, while the validation serves to ensure that the requirements and specifications are also respected in the right way; this phase, in fact, is very delicate as, after the whole process, a perfectly functioning software can be obtained, without errors, but completely useless as it does not reflect what was requested at the beginning.

According to the model applied, this phase is applied to intermediate stages or to the entire software. The verification can be static, if carried out on paper, i.e. on the project, or dynamic, if carried out through the testing of the same software with test data.

As soon as a software has been built, before distributing it outside the company, it is normally subjected to internal testing: we speak, then, of Alpha testing.

Often, when a product has passed Alpha testing, it is distributed externally to a few select customers or even all customers, warning users that the distributed product may not be of high quality and likely requires further corrections. Beta version users can simulate the use of the software in realistic cases and send reports to the manufacturer of the malfunctions found. This type of testing performed free of charge by users is called "Beta testing".

There can be multiple Beta versions as errors are fixed. When the frequency of error reports becomes low, it's time to distribute the official version; Even after Beta versions have been distributed, and therefore in the Beta testing phase, Alpha testing can continue within the company.

Software testing follows rigorous procedural procedures, similar to those of engineering projects: to perform a formal, i.e. rigorously planned, test, a "test plan" is written, which describes in detail how the testing must be carried out.

There are two basic strategies for organizing testing: the "test suite", and the "test scenario". They are often used in combination, that is, one or more test suites and a series of test scenarios are planned.

A test battery is a set of elementary tests, each of which is called a "test case".

A test scenario is a realistic non-trivial use of the software to be tested; while the acceptance tests consider the elementary functions, each scenario takes into consideration a type of user and a likely and complex situation in which this user may find himself. Scenario testing goes through all the steps the user would take in such a situation. Scenario testing is necessarily a system test.

The types of tests that are performed are generally performance, increasing load and stress and, if a version update is introduced, regression tests are also performed to verify that the quality of the previous functionality remains at least unchanged.

However, according to the new methods and standards through which companies approach their suppliers and vice versa, especially if these companies, as in this case, are definitely important and influential in the economy of the general context, it happens that the development phase and implementation of the system, therefore all the technical characteristics, functionalities and applications, costs are discussed, treated, negotiated and agreed between the two parties so that we can reach the best possible compromise in economic and technical terms and that, precisely these last (the technical aspects), are as suitable for the company's vehicles; moreover, the system development phase, which takes place at this point, simultaneously with that of the vehicle, requires that there is a mutual collaboration between suppliers and the company and that, therefore, the resolution of problems and the search for solutions is partialized between the two parts.

From these considerations derives a very detailed methodology of collection and analysis of the anomalies found during testing which is studied and agreed with the suppliers: they make every effort to ensure that the company has all the necessary means to test the systems supplied in optimal conditions. In their vehicles, directly during the testing phase, it is possible to collect useful data in case of bugs or malfunctions of the system through uniquely legible and interpretable logs; therefore the company provides, on the other hand, useful data to the supplier, who is the only one able to read and interpret them in the right way, to indicate development paths with the aim of improving their product and their compatibility with the cars.

In the case of the Cinquecento BEV there are three suppliers of infotainment systems and there are therefore three varieties of systems integrated into the vehicles:

1) R1 High is produced by Harman; this is the most advanced version of the system from a technological point of view and is implemented on vehicles with a high commercial target. This system offers the widest range of features and applications to the user and its interface is present in only one version in what is the largest enclosure and display (NIT, node info – telematic). A system app for smartphones allows the control of some functions, purely in Connectivity use. Both the PROD environment (marketable software version) and the PRE PROD environment (software version for developers) are available in the vehicles of the fleet.

Figure 2-4 Harman logo

2) R1 Low is produced by Melco (Mitsubishi Electric Corporation); in this case the system is of a lower level and is therefore implemented on vehicles with a lower commercial target than the previous one. The interface comes in two versions: the first with a NIT of the same size as the R1 High system and the second with a slightly smaller NIT. It also has its own system app for smartphones. Both the PROD environment and the PRE PROD environment are available in the vehicles of the fleet.

Figure 2-5 Melco logo

3) Smart Audio is produced by Daiichi; in this case it is a basic system, decidedly less advanced but, obviously, also less expensive from a customer point of view. The interface display is even smaller in size than the R1 Low's smaller screen. It also has its own system app for smartphones.

Figure 2-6 Daiichi logo

Figure 2-7 Infotainment system hardware

2.2. TESTING DEPLOYMENT: CHECKLIST OR BY SPECIALIST

The testing methodology adopted by the company requires that each car in the lot selected for Reliability Growth must carry out a predetermined number of km to travel. It therefore happens that the cars are tested in road cycles that are standardized and approved so that the data collection is as consistent and robust as possible.

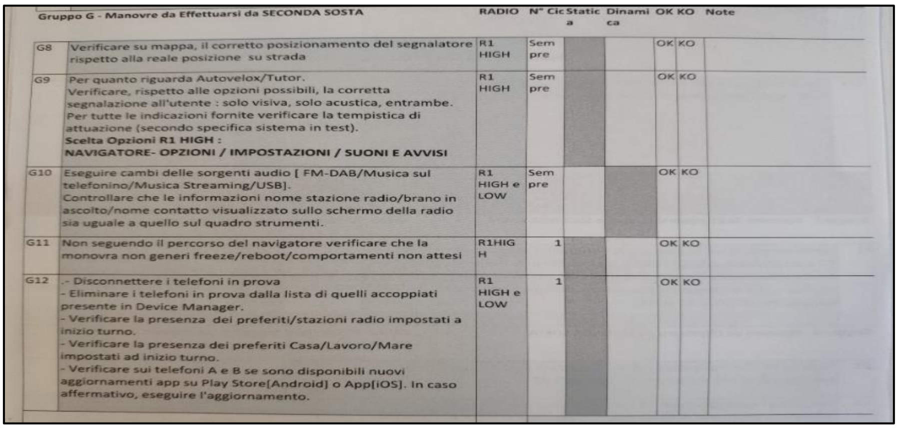
Test driving is generally carried out through the use of a single driver who has the task of verifying the operation of the essentially mechanical and components of the cars, therefore the internal combustion engine and systems connected to it, chassis and bodywork, suspensions and tires, but also electrical/electronic systems, in different modes and external conditions. Instead, for what concerns the testing of infotainment systems, the test driving is conducted differently: for safety reasons and to improve the efficiency of the tests, a second driver is adopted, which is essentially the author of the test, and the trip is shortened to a maximum of 100 km.

Some of the cars in the batch produced for Reliability Growth are instead temporarily entrusted to Infotainment Quality which deals exclusively, as the name implies, with the quality and reliability of the infotainment system and, partially, of others communication systems like telematics box module (TBM) that deals with the connectivity of the vehicle, both in terms of verification and monitoring through testing, and in terms of issue management. These cars are entrusted to the specialists of the division for temporary exclusive use (usually daily or weekly).

2.2.1. TESTING BY DRIVERS THROUGH THE CHECKLIST

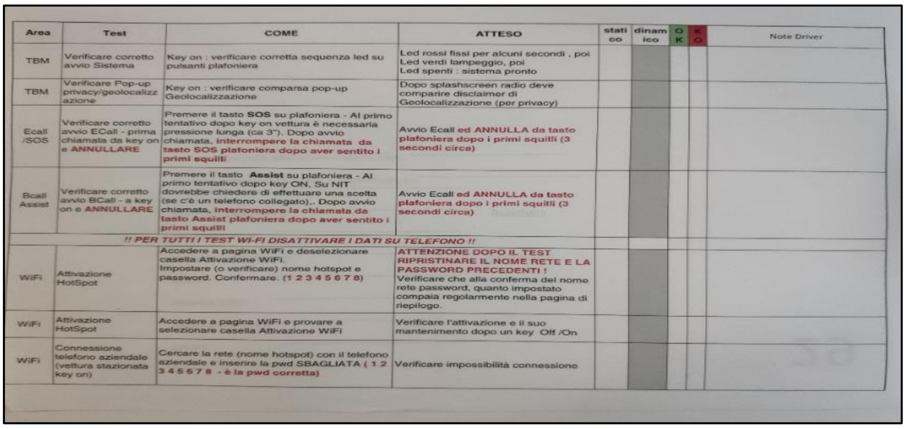
As briefly described above, the infotainment system is tested during road tests by a couple of drivers, one of whom is almost exclusively involved in infotainment use. Clearly, the drivers must be trained by the company on the functionality and method of use of the system in order not to incur technical problems during the test. Part of the test actions are performed in static conditions, others, on the other hand, in dynamic ones.

The infotainment test is conducted by means of two checklists cataloged and approved by RG: the first, marked with number 28, concerns the use of the *RADIO*; the second, marked by number 29, deals with *CONNECTIVITY* checks.



	Gruppo G - Manovre da Effettuarsi da SECONDA SOSTA	RADIO	N° Cic	Statica	Dinamica	OK	KO	Note
G8	Verificare su mappa, il corretto posizionamento del segnalatore rispetto alla reale posizione su strada	R1 HIGH	Sempre			OK	KO	
G9	Per quanto riguarda Autovelox/Tutor. Verificare, rispetto alle opzioni possibili, la corretta segnalazione all'utente : solo visiva, solo acustica, entrambe. Per tutte le indicazioni fornite verificare la tempistica di attuazione (secondo specifica sistema in test). **Scelta Opzioni R1 HIGH :** **NAVIGATORE- OPZIONI / IMPOSTAZIONI / SUONI E AVVISI**	R1 HIGH	Sempre			OK	KO	
G10	Eseguire cambi delle sorgenti audio [FM-DAB/Musica sul telefonino/Musica Streaming/USB]. Controllare che le informazioni nome stazione radio/brano in ascolto/nome contatto visualizzato sullo schermo della radio sia uguale a quello sul quadro strumenti.	R1 HIGH e LOW	Sempre			OK	KO	
G11	Non seguendo il percorso del navigatore verificare che la monovra non generi freeze/reboot/comportamenti non attesi	R1HIGH	1			OK	KO	
G12	.- Disconnettere i telefoni in prova - Eliminare i telefoni in prova dalla lista di quelli accoppiati presente in Device Manager. - Verificare la presenza dei preferiti/stazioni radio impostati a inizio turno. - Verificare la presenza dei preferiti Casa/Lavoro/Mare impostati ad inizio turno. - Verificare sui telefoni A e B se sono disponibili nuovi aggiornamenti app su Play Store[Android] o App[iOS]. In caso affermativo, eseguire l'aggiornamento.	R1 HIGH e LOW	1			OK	KO	

Figure 2-8 Checklist Infotainment



Area	Test	COME	ATTESO	statico	dinamico	OK	KO	Note Driver
TBM	Verificare corretto avvio Sistema	Key on : verificare corretta sequenza led su pulsanti plafoniera	Led rossi fissi per alcuni secondi , poi Led verdi lampeggio, poi Led spenti : sistema pronto					
TBM	Verificare Pop-up privacy/geolocalizzazione	Key on : verificare comparsa pop-up Geolocalizzazione	Dopo splashscreen radio deve comparire disclaimer di Geolocalizzazione (per privacy)					
Ecall /SOS	Verificare corretto avvio ECall - prima chiamata da key on e **ANNULLARE**	Premere il tasto **SOS** su plafoniera - Al primo tentativo dopo key on vettura è necessaria pressione lunga (ca 3"). Dopo avvio chiamata, **interrompere la chiamata da tasto SOS plafoniera dopo aver sentito i primi squilli**	Avvio Ecall **ed ANNULLA da tasto plafoniera dopo i primi squilli (3 secondi circa)**					
Bcall Assist	Verificare corretto avvio BCall - a key on e **ANNULLARE**	Premere il tasto **Assist** su plafoniera - Al primo tentativo dopo key ON, Su NIT dovrebbe chiedere di effettuare una scelta (se c'è un telefono collegato),. Dopo avvio chiamata, **interrompere la chiamata da tasto Assist plafoniera dopo aver sentito i primi squilli**	Avvio Ecall **ed ANNULLA da tasto plafoniera dopo i primi squilli (3 secondi circa)**					
!! PER TUTTI I TEST WI-FI DISATTIVARE I DATI SU TELEFONO !!								
WiFi	Attivazione HotSpot	Accedere a pagina WiFi e deselezionare casella Attivazione WiFi. Impostare (o verificare) nome hotspot e password. Confermare. (1 2 3 4 5 6 7 8)	**ATTENZIONE DOPO IL TEST RIPRISTINARE IL NOME RETE E LA PASSWORD PRECEDENTI !** Verificare che alla conferma del nome rete password, quanto impostato compaia regolarmente nella pagina di riepilogo.					
WiFi	Attivazione HotSpot	Accedere a pagina WiFi e provare a selezionare casella Attivazione WiFi	Verificare l'attivazione e il suo mantenimento dopo un key Off /On					
WiFi	Connessione telefono aziendale (vettura stazionata key on)	Cercare la rete (nome hotspot) con il telefono aziendale e inserire la pwd SBAGLIATA (1 2 3 4 5 6 7 8 - è la pwd corretta)	Verificare impossibilità connessione					

Figure 2-9 Checklist Connectivity

The checklists are organized in a very similar way as they are both characterized by a preamble in which the drivers insert a series of preliminary information useful for tracing the data and test conditions. Then we move on to a real table organized by items cataloged in columns and indexes for the rows; in general, the items in the column are: the area tested, the action, the expected result with possible verification, static / dynamic, OK / KO, driver notes.

The drivers conduct the tests precisely following the instructions on the checklists, trying to perform the required actions even more than once and under different conditions during the duration of the road trip if necessary. Obviously the schematization and repetitiveness of the procedure generates a large amount of data useful for making a statistic of the results obtained but inhibits the possibility of verifying unconventional or rare actions.

Testing managers also provide drivers with standardized forms for filling out the detection of an anomaly with a simplified and sequential format.

MODULO ANOMALIA INFOTAINMENT	COMPILATORE:		**LEGENDA:**
ID VETTURA (VP.. o PS...):		DATA:	**SW** = SOFTWARE
MODELLO TEL. FAVORITO 1:	RG n°	SW TEL. FAVORITO 1:	**TEL** = TELEFONO **BT** = BLUETOOTH
MODELLO TEL. FAVORITO 2:	RG n°	SW TEL. FAVORITO 2:	**CP** = CARPLAY
APP MYUCONNECT O COMPANION:		SW :	**AA** = ANDROID AUTO
N:B: importantissimo fare acquisizioni da acquisitore CT e RADIO , e fare acquisizioni indicando anche il ripristino			DEMERITO:
TITOLO PROBLEMA:			1☐ 10☐ 50☐ 100☐

Condizioni Iniziali: Stato in cui si trovava la Radio (NIT) prima del problema	**CONDIZIONI VEICOLO:** STATICHE☐ DINAMICHE☐ **CONNESS. TEL 1:** NO☐ TEL BT☐ MEDIA BT☐ MEDIA USB☐ CP/AA via USB☐ CP/AA wireless☐ CARICA☐ **CONNESS. TEL 2:** NO☐ TEL BT☐ MEDIA BT☐ MEDIA USB☐ CP/AA via USB☐ CP/AA wireless☐ CARICA☐ **NAVIGAZIONE:** NO☐ ALTRO: NATIVA☐ CP☐ AA☐ **RIPROD. AUDIO:** NO☐ FM☐ AM☐ DAB☐ USB 1☐ USB 2☐ SD☐ TEL 1 BT☐ TEL 2 BT☐ TEL 1 CP/AA☐ TEL 2 CP/AA☐ **CHIAM. IN CORSO:** NO☐ SU TEL 1☐ SU TEL 2☐ SU TEL 3☐ **NOTE:**
Azioni: Quale azione pensi che abbia causato il problema?	
Problema: Comportamento non corretto osservato. (descrivere quanti più dettagli possibile)	**FREQUENZA:** UNA VOLTA NEL TURNO ☐ SALTUARIAMENTE ☐ SEMPRE NEL TURNO ☐ ACQUISIZ. RADIO☐ COD. ACQUSIZ. ACQUISIZ. CONTROLTECH (tasto rosso)☐ Km: ora
Ripristino del sistema: Azione per ripristinare il corretto funzionamento (Es: key off/ sosta lunga)	 ACQUISIZ. RADIO☐ COD. ACQUSIZ. ACQUISIZ. CONTROLTECH (tasto rosso)☐ Km: ora

Table 5 Infotainment fault module

2.2.2. TESTING BY SPECIALIST

For this reason, but even more so due to a stronger link with the managers and directors of the quality sector (in this case of infotainment), the testing conducted by the system specialists is considered the most reliable and consistent. The specialist is an employee trained and employed for the exclusive use of a particular system; in the case of infotainment this is aware of all aspects concerning the radio, the instrument panel, the TBM (telematics box module) and their integrated circuits, they also know the ways of access, configuration and use, both at hardware and software level.

As a main activity, the specialists conduct the tests individually and freely, that is, they follow their instincts, clearly on the basis of their knowledge and experience, looking for possible anomalies and errors (bugs), malfunctions or dislikes which, often, are not detected during test driving on the road from system agnostics. Consequently, it is easy to understand how in reality the drafting of checklists is often revisable and revised based on the indications and advice that specialists provide to testing managers.

When a specialist identifies a bug or a dislike, he presents the problem to the reliability managers according to a standardized procedure: by means of a suitable detection procedure in the car and the use of special software for data storage they upload the issues found to the database, also giving a description of the conditions and details of the event that circumscribes the issue itself. Instead the anomalies found and filed by the drivers are loaded by the RG testing managers on the database.

They also refers to a sort of checklist which is actually simply a reminder / history of previous anomalies, for both Infotainment and Connectivity functions, stored in a folder in the company drive with access limited to tester only, cataloged according to the name of the car project and the commercial name of the Infotainment system.

Numero issue	Descrizione severity	Descrizione breve	Descrizione issue	Serial	Mileage	Data rilevamento	GIM Issue Nr	AreaCar	GIM Status
7507	100	Comfort Page doesn't work after changing Drive Profile	PS26 R14E PREPROD TBM 4.24C PREPROD (22-9 ore 9.44) LOG USB su drive per dimensioni REPRO TEST MUST FIX [redacted] Vettura in ready , profilo driver 1 attivo. Effettuo cambio profilo a profilo 2, il profilo si attiva con i settaggio previsti ISSUE : selezionando la pagina Comfort da category bar ,non si riesce ad accedere, Non è possibile accedere neanche dall'icona nell'app drawer Recovery : nessuna Vehicle ready, driver profile 1 active. I change profile to profile 2, the profile is activated with the foreseen settings ISSUE: selecting the Comfort page from category bar, you cannot access, You cannot access even from the icon in the app drawer Recovery: none	PS26	46620	22/9/2020		Infotainment	
7505	100	NAV : map repetition on IPC takes long time to upload	PS26 R14E PREPROD TBM 4.24C PREPROD (22-9 ore 9.22) LOG USB su drive per dimensioni REPRO TEST MUST FIX [redacted] Vettura in ready , imposto una navigazione, e porto IPC a pagina Navigation ISSUE : su IPC persiste messaggio Caricamento Mappa per lungo tempo . Recovery : cambio pagina IPC e ritorno, la mappa è regolarmente presente e funzionante coerentemente a HMI HU Car ready, set a navigation, and set IPC to Navigation page ISSUE: Loading Map message persists on IPC for a long time. Recovery: change of IPC page and back, the map is regularly present and working consistently with HMI HU	PS26	46618	22/9/2020		Infotainment	

Table 6 Extract of anomalies database

2.3. MANAGEMENT OF THE PROBLEMS DETECTED

Essentially, whether an error has been detected during a test driving or if it has been identified by a specialist, the procedure for the acquisition of errors (logging) and the management of the data acquired by logging is roughly the same; only the logging mode varies in some respects, in particular due to the type of infotainment system of the vehicle in question, therefore depending on the use of R1 High, Low or Smart Audio in the case of Cinquecento BEV.

2.3.1. LOG IN VEHICLE

When a bug, a misbehavior or a dislike occurs, whether it happens in a single occurrence, sporadically or if it occurs systematically, the log is an essential and indispensable step in the infotainment testing process. The variety of logs is based on the type of system used in the car and the type of section tested (*infotainment* or *connectivity*), basically they are of two types: internal system log and CAN signal log.

As far as the radio is concerned, tracing of signals inside the system and screen captures are used (via USB key inserted on the dashboard and pressing on a preferential physical button, for Cinquecento BEV is the rear window heating for the PRE-PROD software and the max a/c flow for the PROD software); in addition to being collected on the USB pen drive, they are also automatically sent to the system supplier's anomaly collection server, which will take care of any interventions.

Figure 2-10 USB logging

In RG, from an external supplier (Aptiv – Control Tec), a special instrumentation for the detection and storage of CAN signals useful for discerning and cataloging the issues is also inserted on all the cars in the fleet.

Figure 2-11 Control Tec modules

As regards connectivity problems, a standard procedure is available which involves the use of the pre-prod (Beta version) vehicle app for smartphones initially intended for testers (in the marketing phase the app is "cleaned up" and made usable from a customer perspective).

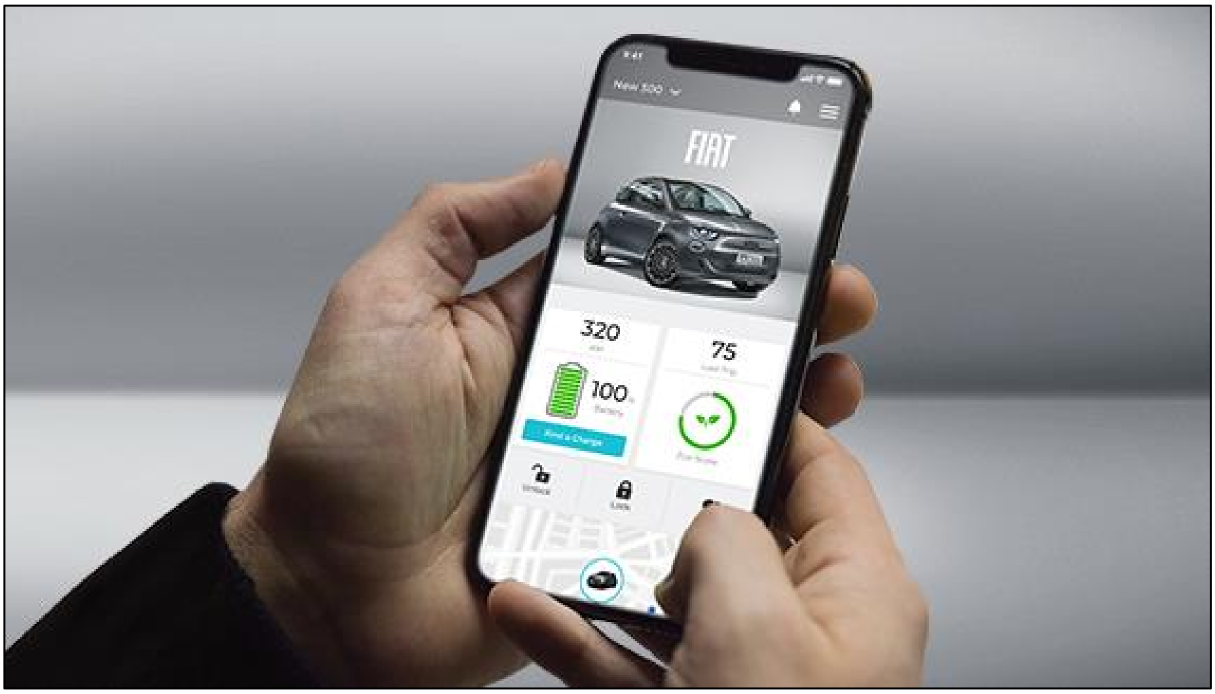


Figure 2-12 Smartphone App

2.3.2. IMAN

Once the logs have been made and the signals limited to the problem encountered have been acquired, it is necessary to insert in an *ad hoc* database all the data coming from the manual surveys of the drivers and specialists: the internal management software of this database is Iman, aka Issue management. Clearly it is used for any type of anomaly, both software such as Infotainment, and components or systems

Iman is therefore a schematic database that collects all the issues detected, catalogs them according to a predefined model and makes them available for analysis by reliability and quality managers and diagnosis references. Clearly, the methods for entering an issue must be explained and understood upstream of the acquisitions so that both the drivers and the specialists can adequately provide all the details and technical information in an understandable and exhaustive way to facilitate the work of managers in terms of problem qualification. In fact, starting from the training of specialists and drivers and from the drafting of the checklists, the items integrated in Iman are considered and codified to simplify not only the work of managers who find themselves available to unambiguous information but also that of the first in the interpretation and qualification of the issue.

The main factors that determine the discrimination between the issues are: occurrence, severity, time of the event and km to the odometer, boundary conditions (in particular Infotainment system sw version), actions, possible manual acquisition by means of the data logger (preferable supported by video report, camera oriented on NIT) and/or USB pen drive, recovery. The prioritizing factor is severity: each category in the severity table has its own weight in the quantification of the problem and must be analyzed separately from the others through as much useful information as possible.

Frequenza dell'anomalia (Occurence)		Tipologia della funzionalità (Type of feature)		Complessità della sequenza scatenante (Stimulus complexity)		Tipologia dell'anomalia (Failure Classification)		Impatto dell'anomalia (Impact Category)		Modalità di ripristino (Recovery)		Severity	
Systematic / Sporadic (> 70%)	1	All/Safety/Main function	1	Spontaneous/none	1	Loss of functionality	1	All	1	None	1		
Sporadic (≥ 30% and ≤ 70%)	0,5	Secondary function	0,5	Single action	0,7	Misbehaviour - logic/Degraded Performance	0,4	Customer	1	Battery Disconnection	1		
Once (<30%)	0,1	Service functions	0,3	Double actcion	0,1	Logic/appearance/dislike/aesthetic aspect	0,005	Plant	0,5	NETOff/NETOn	0,5		L100>0,003
		Informative	0,2	Multiple action (equal or more than 3)/very rapid actions	0,02			Service	0,1	Specific activation/sequance of commands	0,7		L50=0,003 to 0,0012
								NONE	0,001	Key OFF/ON transition	0,1		L10=0,00112 to 0,0000105
										Knob Off/On	0,03		L1 <= 0,00001
										Generic activation (every button or icon)/single & logic activation	0,03		
										Spontaneous	0,02		
Frequenza dell'anomalia (Occurence)		**Tipologia della funzionalità (Type of feature)**		**Complessità della sequenza scatenante (Stimulus complexity)**		**Tipologia dell'anomalia (Failure Classification)**		**Impatto dell'anomalia (Impact Category)**		**Modalità di ripristino (Recovery)**		**Severity (calcolo matematico)**	**Severity calcolata**
Once (<30%)	0,1	Secondary function	0,5	Single action	0,7	Misbehaviour - logic/Degraded Performance	0,4	Customer	1	Spontaneous	0,02	0,00028	L10(LOW)

Table 7 Severity Table

Obviously, when the database is enriched with very frequent, very serious or both (the worst) issues, the managers' report, with all the supporting data logged, the presence to diagnosis responsible and specialist technicians for the solution.

Briefly summarizing, it is clear that the close collaboration between the various Infotainment Quality managers and, no less important, between testing managers and specialists is indispensable: the clearer, more consistent and univocal the communication, the more the generation of useful data and information benefits and assumes an important effectiveness in terms of correction and resolution of problems. At the basis of this, there is the definition of a method that must be repeated and optimized progressively to make the process as efficient as possible.

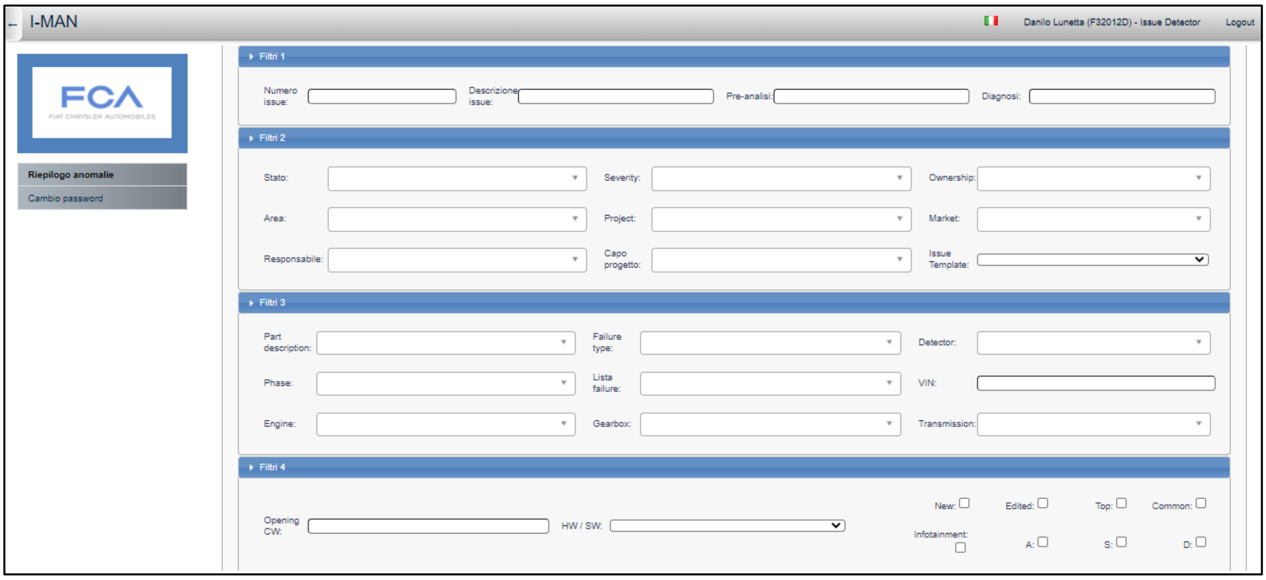


Figure 2-13 Iman interface

3 INTEGRATION OF A NEW METHODOLOGY THROUGH THE USE OF THE ROBOT PLATFORM: PREREQUISITES AND TEST CASE STUDY

This and the next chapters deal with the integration of the robotic platform into the environment and operating context of Quality Infotainment, focusing on the purely technical aspects that link the company's traditional testing methodology with the highly advanced robotic technology of the Comau machine.

Surely it was not an easy project to complete and that required a considerable amount of time, also due to the global event of the pandemic, and an effort and use of resources, both in terms of personnel and structure and economic, not indifferent.

The project stems from the need and the desire to improve and consolidate the levels of testing efficiency at high standards, first of all trying to strengthen the traditional methodology and, subsequently, finding an independent scope, always focusing on the methods of use from a customer perspective. From the physical implementation of the system to the development of the software, every technical and functional detail of the platform has been designed and built for this purpose.

Thanks to these sought-after characteristics it was possible to work to achieve the aforementioned purpose effectively, without forgetting, receiving considerable support from the main complementors of the project, RG and Quality Infotainment in FCA and Comau Electrification and Robotics.

3.1. DEFINITION OF A TEST SUITE AND SEARCH FOR REGISTERED ANOMALIES

The first step of the process was training on procedures, nomenclature, regulations, ways of acting that regulate the Quality Infotainment division; starting from these notions, entering into the details of testing was simpler and more effective, especially in understanding the characteristics of the object and the way in which it is tested.

With these assumptions it was then necessary to find a meeting point with automation technology in which everything that is feasible by the human can be translated into an automatically possible action. The synthesis of this merger took shape in the creation of a schematized database, an excel mask/table/suit whose characteristics fully reflect the contents of the tested object and, at the same time, exploits as a model conceptually recognized and acquired by the company such as the CHECKLIST.

It is precisely from the checklist that the mask takes the structure in a certain way, in the sense that the subdivision of features in columns and descriptive items on each row has been assimilated by the model or template of the checklist. As will be seen later, even the features are partly equivalent or similar precisely to seek continuity of thought with the RG line and establish the first points of contact with the traditional methodology.

To fill the mask with all the items corresponding to the characteristics designated for testing, it was decided to carry out a complete examination, strictly following the customer's way of acting, of the Infotainment system interface with consequent breakdown into categories of use and functionality.

Before proceeding to the details it should be noted that the car assigned for testing through the robotic platform during the preliminary phase, as already mentioned in the previous chapter, was the VP107 (initials of recognition and internal traceability for RG) which is equipped with Harman's R1 High Infotainment system (to which software updates were periodically performed); therefore the categories that can be distinguished from the customer's point of view and that have been selected refer to the aforementioned system which, as specified in chapter 2, is the most advanced and complete in terms of functionality.

The uniquely distinguishable and individually treatable categories on the Infotainment HMI are therefore:

- **Status Bar (on top)**
- **Home**
- **Media**
- **Comfort**
- **Navigation**
- **Phone**
- **Vehicle**

To these must be added some applications of particular interest to the user such as **VR**, aka Voice Recognition (usable in native environment or in projection mode), the **System Keyboard**, the **Key cycle**.

The only category that is always visible on the HMI in extended mode and always accessible by the user is the Status Bar which contains individual applications of some particularly relevant or unavoidably easy to reach categories, such as the clock or the app drawer. Furthermore, the remaining categories mentioned above are collected on the left of the HMI in a vertical bar called Category Bar.

Below an example of typical NIT HMI, i.e. Home screen with Media and Telephone widgets.

Figure 3-1 HMI radio

3.1.1. TEST SUITE

Returning to the mask, we can therefore understand how the structure can easily be adapted to the breakdown into categories above: each category has sub-categories to which one or more items correspond; it follows that also the items on the rows are divided into univocally identifiable groups and consequently filterable for a detailed analysis.

The features in the column, as previously explained, follow the checklist model but are adapted to the broader and more detailed structure. Therefore, the column features are as follows:

- **Category**
- **Subcategory 1**
- **Subcategory 2**
- **Actions**
- **Verification and expected**
- **Notes**
- **System software version**

Categoria	Subcategoria	Subcategoria 2	Azioni	Verifica e atteso	Note	System software version

Table 8 Features of the mask

The basic idea for the level of detail of the decomposition lies in the possibility of making a single row as modular as possible and subsequently attributable to test cases that are simply implementable and interchangeable in the test sequences; it follows that a line, or at most two/three, univocally corresponds to a test case that can be carried out by the robot.

Clearly each category has its own degree of complexity and expansiveness, so the table is more populated for some of them and less populated for others.

As in the case of the checklists, a preamble has also been created for this mask which contains a brief description of the test and details of the vehicle tested.

Test statico con Robot Comau su sistema Infotainment
332 500 BEV VP 107

Table 9 Heading of the mask

It is important to underline that each test is designed from a customer perspective but also to be performed by the robot so that it can perform it without incurring problems that could compromise its own functionality or that of the car, therefore the tests are static, do not involve any destructive action and they do not change the system software in any way, they only aim at modifying settings or profiles, performing only actions that involve reversible changes. For this reason (but as we will see later, it is not the only one) it follows that some tests are not possible and the lines that identify them are filled with red.

Veicolo	Impostazioni	Aggiornamento software		Appare la voce Download software via Wi-Fi (spunta)

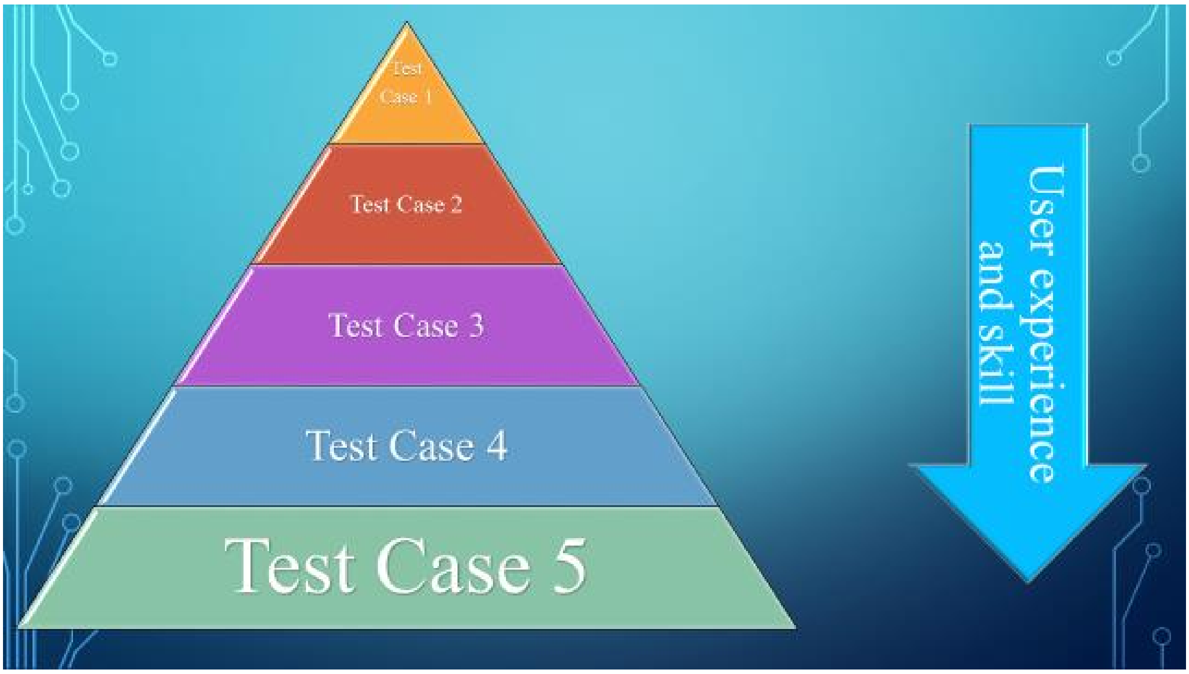
Table 10 Example of red row

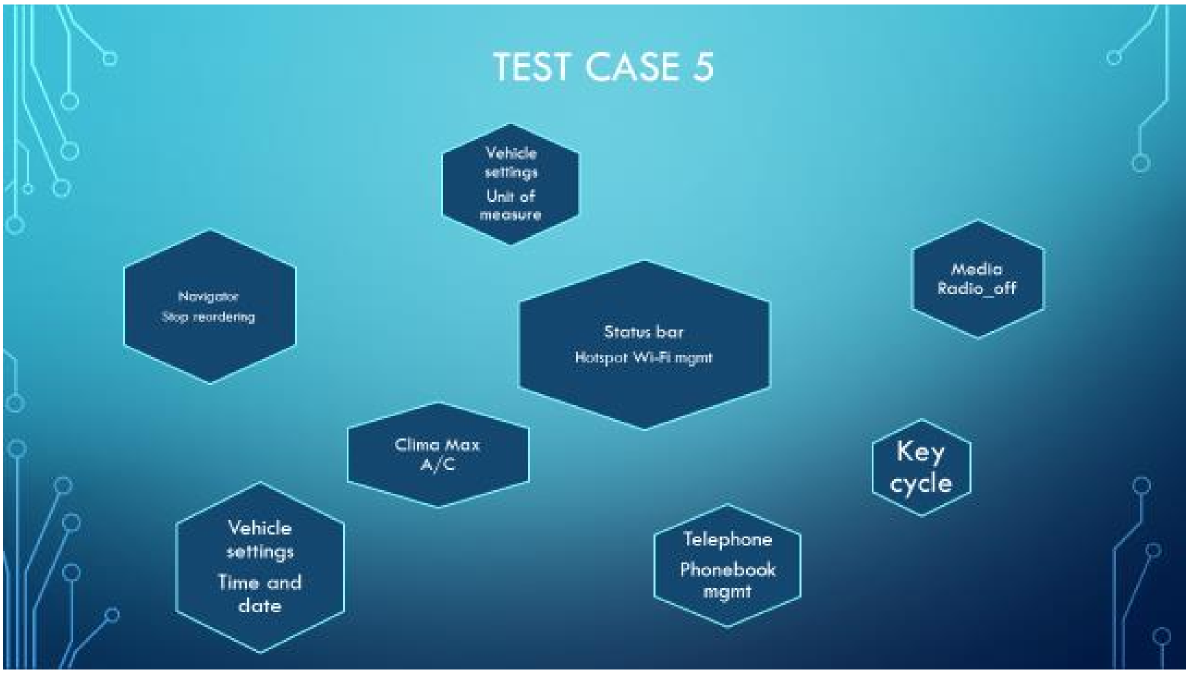
To conclude, this mask can be summarized as a sort of reference database for the search for particular functions or applications to be tested, individually, in sequences made up of tests that analyze a single category or a mix of categories; it is therefore possible to exploit the information contained in several ways, such as the analysis of a single possible anomaly or simulate the behavior of a customer in using the system in various situations.

Test statico con Robot Comau su sistema Infotainment						
332 500 BEV VP 107						
Categoria	Subcategoria	Subcategoria 2	Azioni	Verifica e atteso	Note	System software version
Key ON/OFF						
Home						
Status Bar						
Media						
Comfort						
Navigazione						
Telefono						
Veicolo						
Tastiera & VR						

Table 11 Overall structure of the mask

An example that can give an idea of the above is represented by the test cases implemented for the Buy off of the Dexterity software: on this occasion, 6 test cases were created in order to show and demonstrate how the functions declared by Comau in the development are actually active and verifiable in the package sold. In particular, each of the first five test cases (the sixth had other purposes) simulated the use of the system by users with a certain level of experience and skills; the modules that made up each test case were extrapolated from the mask and then assembled in sequence according to a model of random use.





3.1.2. REGISTERED ANOMALIES: SPECIFIC TEST CASES

From what was deduced from the analysis of anomaly management by the Quality division in chapter 2, access to information on the anomaly history is the main source for the improvement of the product under development: first of all as a reference for the definition and qualification of the issues in terms not only qualitative but also quantitative and, therefore, with defined priorities so that technicians know a priori where and when to analyze and intervene; in second analysis it serves to circumscribe the occurrence and the surrounding conditions of an anomaly so that the event is replicable and, therefore, can be analyzed individually and defined, if necessary, in an even more detailed way for better management of the interventions to resolve the cause that induces it (this second instance is a specific procedure in FCA and is called "reappearing").

It is evident that the test cases of the mask must necessarily simulate the above situations to intercept the anomalies that have been stored in the Iman database.

This assertion is not verified a priori as the single anomaly can present itself in different ways and under different boundary conditions; fortunately the issue loading procedure is deeply precise and practically the vast majority of conditions can be recreated in a test programming environment (test editor) provided that the path that leads to determine the aforementioned conditions of that particular issue can be exploited by the robot.

Below you can see an example of the circumstance of the anomaly:

VP109R1H MML1067 TBM4.20 (23-6 ore 15.16) SCREENSHOT ACQUIRED Radio ON, access the ELECTRIC VEHICLE PROGRAMMING menu I do reload programming, save it. ISSUE: returning to the programs page, the programming performed is not displayed. Recovery: page change and return to the programming page: when returning, the programming is correctly displayed.

Table 12 Example of registered anomaly

In summary, two constraints must be respected:

- It is possible to define the boundary conditions through the test cases and carry them out by means of the robot.
- It is possible to intercept and capture the anomaly by reporting an error when reproducing the test or, subsequently, in the report environment (DIAdem NI).

If even only one of these two constraints is not respected, it is not possible to reproduce the issue or intercept it. On the contrary, if the conditions are met, it is certainly possible to create test cases that can reproduce the detailed situation and allow the issue to be analyzed.

It remains to be understood whether the actions that serve to create the boundary conditions and allow intercepting the issue have already been inserted in a test case of the mask, which has been implemented to range to the limit of the allowed each combination of interface status , or it is necessary to write a new specific test case that expands the contents of the mask, as would be done in a database that collects all the combinations of the outputs coming from a series of circumscribed events. Therefore, by definition, the mask can be perfected according to a development that is as complete and detailed as possible, it is a constantly updated database until the limits determined by the potential of the robot or the knowledge of Infotainment system of a particular vehicle are reached.

3.2. DEFINITION OF TEST CASES AND SEQUENCES

The test cases are undoubtedly the focus and source of the applications of the robotic platform, from which the execution and simulations take shape and can be modified according to the specification, the feature, a certain expected behavior, a stored anomaly that you want to intercept. It is therefore clear that the drafting and optimization of test cases is the process that supports and catalyzes the completion of the simulation and the consequent analysis of the behavior of the Infotainment system under predetermined conditions.

Obviously, in relation to what is described in the previous paragraphs, to better catalog the single test case and make it modular to achieve the need to span all the combinations of conditions and circumscribed events, the test cases are written in a concise and targeted way, so they are built exclusively to perform a single or a small amount of actions in a single category and check them for the verification of the expected result; they are therefore composed of a relatively small number of lines: the range varies between 15 and 40/50 units, except for some longer ones due to more complex and stringent controls.

Given the need to perform more complex and structured tests compared to the verification of a single action to optimize testing times and stress the system more by simulating its customer behavior, it is possible to overcome the problem by generating test case sequences that contain a certain number and in a certain order that serves to recreate certain conditions.

3.2.1. TEST CASES

The drafting of the test cases takes place in the Test Editor environment of the Dexterity sw, the characteristics of which have been analyzed in chapter 1.

Although each test has been made up of different actions according to the purposes, it is possible to identify a recurring structure in their composition:

- First of all, the action that initializes the test is the move-align; it is necessary to carry out a control check on the correctness of the positions stored during the calibrations and to set the initial positions and conditions of the robot before carrying out any test.
- To access certain categories or certain menus of the Infotainment interface it is necessary to recognize the icons, on the display or on the keypad, which identify them; therefore look actions are performed, both of image and text type, to find them and move, type touch or swipe, to reach the interface sought in the development phase of the single test, considering the possible use of offset (and length of the swipe) if it is necessary to refer to known positions or icons or according to the limits determined by the characteristics of the interface.

  To give an example, to reach the Reorder Stops icon in the Options menu when driving is started (Navigation), it is necessary to perform two swipe-ups of different lengths, first using the Find Alternative icon as a reference (with offset for the starting point touch of the swipe) and then the Avoid Part Of Route icon; this happens because this menu has a fairly complex interface and the robot's capabilities allow it to be managed only by passing over several actions. There are also compilation alternatives but, in the optimization phase, the best solution is always sought in terms of the number of necessary actions and achievement of the expected result.

look	text	Opzioni	-
move	touch	26	offset:0.0,0.0
look	image	trova_alt.jpg	-
move	swipe up	28	offset:27,0 length:70
look	image	evita_parte.jpg	-
move	swipe up	30	offset:0,0 length:65
look	image	reord_soste.jpg	-
move	touch	32	offset:0.0,0.0

Figure 3-2 Test case example 1

- Once the desired interface is reached, essentially actions are carried out inside that modify the state of the interface or of the entire system; this is achieved, also in this case, through the look and move actions and, in the case of using VR, the reproduce action. To change the state of the system there is a considerable variety of specific actions but it is worth emphasizing the use of reproduce-voice, look-keyboard, move-program, move-keep pressed and, the most used of all, move-touch.

  Furthermore, if the system takes an extended period of time to change its state, the wait action is used, in particular the wait sleep if it is necessary to perform manual actions on the system or on the conditions in which it is.

- The most important aspect of the whole test case lies in the control and verification of the wait where the robot is able to detect any anomalies or if the test has been performed correctly and the system has reacted following the desired behavior to specification. Here the actions are as follows: look, listen, veristand, store, compare; each of them obviously has its own method of use but all of them can be used for the purpose of monitoring and qualitative and quantitative verification of an expected event.

- If it is necessary to carry out cyclical or iterative actions, both for changing the state and for monitoring / control, the go to-line action is used, usually setting binding conditions on certain lines.

13	-	look	image	sosta.jpg
14	13_nok	look	text	Opzioni
15	13_nok	move	touch	14
16	13_nok	look	text	Panoramica
17	13_nok	move	touch	16
18	13_nok	go to	line	13

Figure 3-3 Test case example 2

- After checking the expected result, it is possible to return to the initial status of the system and, if necessary, to the menu or initial pages of the category being tested if the test case was positive; if, on the other hand, an anomaly has occurred, the test case is stopped and, generally, the condition / action go to-fail is imposed.

The structuring of the test cases practically always follows this construction model, what clearly changes is the content of the actions which therefore determine different paths in relation to the event to be recreated and analyzed.

It is necessary to make a note about some types of actions that the robot is able to perform but which the metalanguage of the Dexterity Test Editor has not configured a priori: these are the move-programs which, as described in chapter 1, are precisely programmed manually on the TP5 of the Small robot; they allow you to perform unconventional actions because:

1. they may not act on the display and move out of it on the dashboard of the car
2. they allow movements and actions in a non-linear direction (with a certain angle in respect to the horizontal)

Among the most important are undoubtedly:

- pressing the key-on button
- the pressure on the climate buttons
- oblique swipe

The example below shows the use of the move-program "key_on_500" which, as the name implies, presses the ignition key of the vehicle. The action is inserted in the test case like any move but does not use any image or text as a reference.

ID	Condition	Action	Type	Arg1
0	-	move	align	-
1	-	look	black screen	-
2	1_ok	move	program	key_on_500
3	1_ok	wait	seconds	10
4	-	look	image	home.jpg
5	-	move	touch	4

Figure 3-4 Test case example 3

3.2.2. TEST SEQUENCES

As has already been expressed, the single test case is very short and specific, it does not allow the simulation of a wide range of actions unless the number of lines becomes much higher than the standard previously indicated (max 50 lines).

It is also possible to use "sub test cases" or "nested test cases" to enrich the single test case with actions and situations to test.

Below an example of a nested test case called via the execute-test case action is showed.

Test Case [redacted]/KeyON _Pop-up_Geolocal.csv

ID	Condition	Action	Type	Arg1	Arg2
0	-	execute	test case	key_on.csv	-
1	-	wait	seconds	5	-
2	-	look	text	Geolocalizzazione	-
3	-	look	image	ok.PNG	-
4	-	move	touch	3	offset:0.0,0.0
5	-	look	image	geo_on.jpg	-
6	5_nok	goto	fail	-	-

Test Case [redacted]/key_on.csv

ID	Condition	Action	Type	Arg1	Arg2
0	-	move	align	-	-
1	-	look	black screen	-	-
2	1_ok	move	program	key_on_500	0
3	1_ok	wait	seconds	10	-
4	-	look	image	home.jpg	left
5	-	move	touch	4	offset:0.0,0.0

Figure 3-5 Test case example 4

However, the use of nested test cases to enrich the test case as a whole does not coincide with the idea of flexibility and modularity required: the structure of the test case lengthens a lot and, above all, is rigid in the meaning that the robot performs precisely the actions that follow one another along its own lines without the possibility of performing other actions in between.

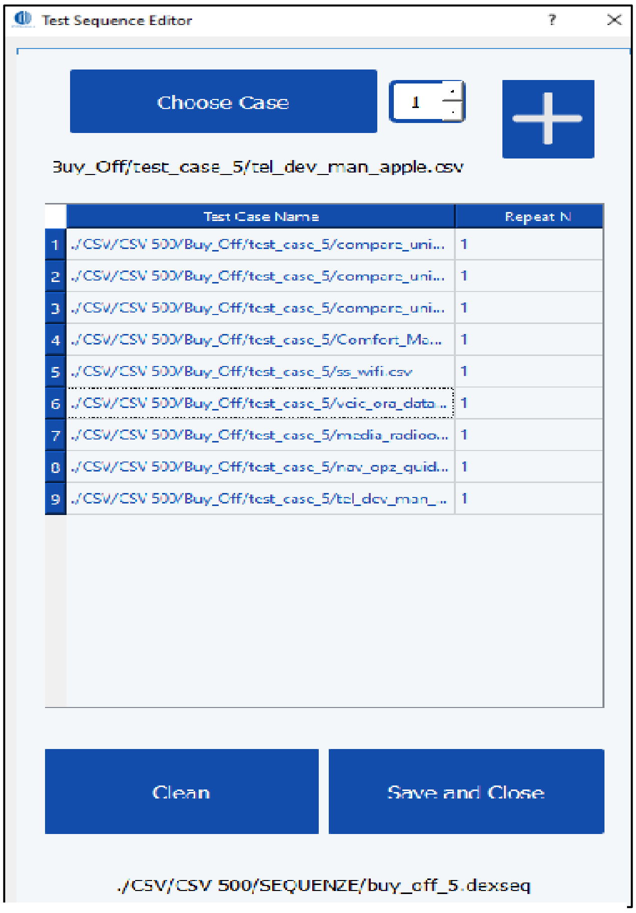


Figure 3-6 Test sequence example

In order to achieve the main goal, the test sequences were therefore designed: these are files of different formats compared to the test cases (dexseq instead of csv), the only format read for the execution by the robot, and are composed, also in this case as the name recalls, by test cases in sequence.

Clearly this solution offers a much higher level of flexibility as it allows you to arrange the individual test cases in the order you want; it is therefore convenient, as mentioned above, to write short and specific test cases that can be positioned at will in a sequence without losing its meaning provided that the single test case itself has a precise definition and a purpose known.

Each test case in the sequence can be repeated more than once but also for the whole sequence there is the same possibility: when a sequence is repeated more than once, the unit is defined "round", a number is assigned to each one which iteratively grows with increasing repetitions.

The example above shows a sequence of test cases designated for the Buy off of the Dexterity software.

So the modularity and the flexibility of the test cases must be exploited through the sequences given that any test case can be inserted and in the order that is considered appropriate; through these features it is possible to exploit the characteristic mainly sought by the Quality body, that is the possibility of automating the exploitation and use of the Infotainment system as an average user or a skilled user would do, at the same time increasing the level of stress that occurs generates on the system given that tests within the sequence or the sequence itself can be repeated up to N iterations, where N is an indefinite number. As we will see later this is a fundamental benefit of using the platform.

The table and images below show an example of a test case inserted in the sequence used for the buy off of the software and the related data contained. This is the test case: vehicle_evpages_charging_settings.csv

ID	Condition	Action	Type	Arg1	Arg2
0	-	execute	test case	veic_default	-
1	-	look	text	Veicolo elettrico	-
2	-	move	touch	1	-
3	-	look	text	Launch EV pages	-
4	-	move	touch	3	-
5	-	look	text	Impostazioni ricarica	-
6	-	move	touch	5	-
7	-	store	file	5	“min_time1”, offset 10,30 , size 20,35
8	-	look	image	car	-
9	-	move	swipe right	8	offset 10,150 , length 30
10	-	look	text	Impostazioni	-
11	-	store	file	10	“min_time2”, offset 10,30 , size 20,35
12	-	compare	image	min_time1	min_time2
13	12_ok	go to	fail	-	-
14	-	move	swipe left	8	offset 10,150 , length 30
15	-	look	text	Impostazioni	-
16	-	store	file	15	“min_time3”, offset 10,30 , size 20,35
17	-	compare	image	min_time2	min_time3
18	17_ok	go to	fail	-	-

Table 13 vehicle_evpages_charging_settings.csv

The test case begins with the execution of a nested test case "veic_default" which leads the system to the vehicle screen: it is therefore used to carry out a repetitive and high-frequency action and frees the user from writing it many times on one or more test cases.

At this point you are then on the Vehicle category screen and proceed with the first programmed actions: a series of look-text and move-touch which allows you to interface with the screen where you will make the status changes and controls, i.e. the charging settings menu of the electric vehicle pages. The most interesting aspect of this series of actions is undoubtedly the result of the combination of software-vision system use: when the user writes the test case, he knows a priori the interfaces that will be displayed in execution and therefore asks the software to intercept the requested objects through the vision system, consisting of camera and recognition algorithm. The result is the following.

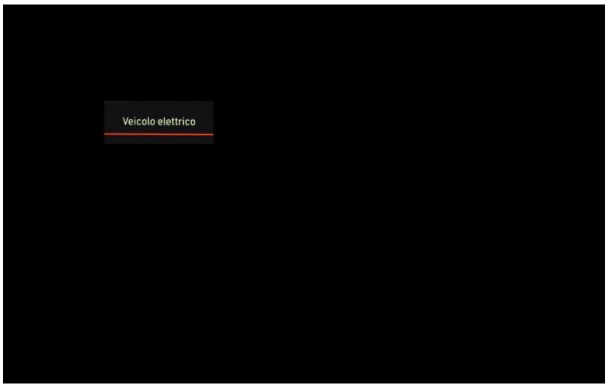


Figure 3-7 Charging settings example

Figure 3-8 Charging settings example

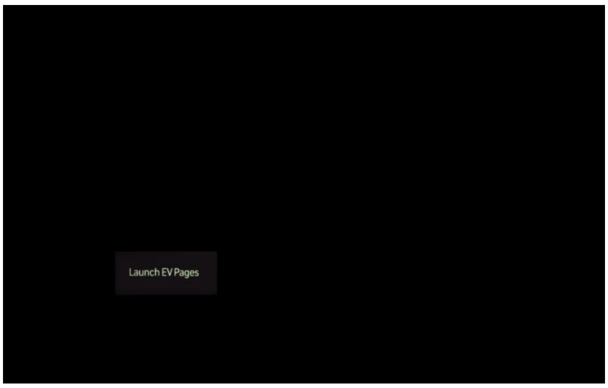


Figure 3-9 Charging settings example

Figure 3-10 Charging settings example

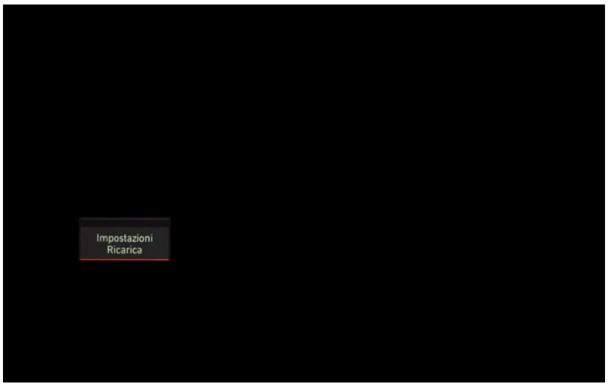


Figure 3-11 Charging settings example

Once you have reached the desired menu, you can perform: store an image that represents the initial state of the system, swipe the pointer on the numbered bar to change the initial state, store for checking the status change, compare as a control on the change, swipe the pointer to return to the initial state, store and compare for checking. After the appearances there are go to fail with conditions that serve to determine the failure of the test if something did not go as expected.

In this sequence of actions, the most interesting aspect is that of the compare which verifies through the matscore algorithm whether two images are equal or not. Below the results of this particular test case based on the compare of images acquired through the store.

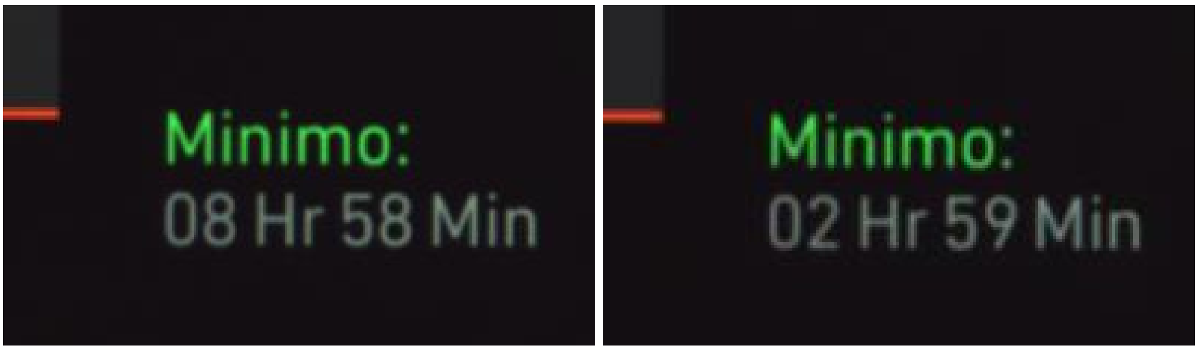


Figure 3-12 Charging settings example

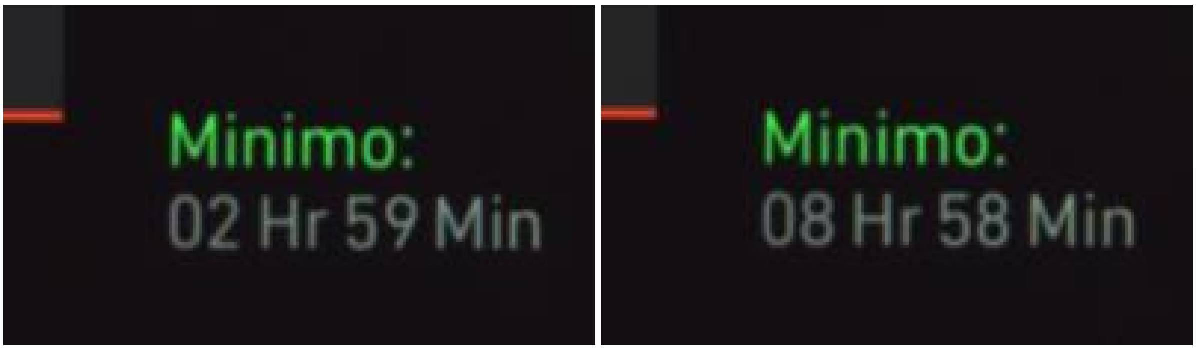


Figure 3-13 Charging settings example

Finally, it is possible to understand how this test can easily be inserted in any sequence since it does not foresee particular initial conditions, it modifies and restores the system state in a completely independent way and it can be followed by any test case. In summary, the test case can be seen as an independent piece of a sequence that does not necessarily have to follow a precise logic but must certainly respect some constraints for implementation.

4 INTEGRATION OF A NEW METHODOLOGY: EXECUTION PROCESS AND ANALYSIS OF DETECTED DATA

This chapter describes the execution of the test and all the actions and information deriving from it, in particular it will deal with the analysis of the detected data that is the output required by Quality for the development and improvement of the system.

4.1. DESCRIPTION AND STUDY OF THE EXECUTION

The title of the chapter indicates the word "Simulation" and this choice is mainly dictated by two reasons:

1. Indicating test execution with "test case" may be ambiguous since the files compiled for execution are also called test cases.
2. The test execution consists of a real simulation of the use of the Infotainment system by any user, as has already been extensively described in the previous chapter. Alternatively, if you decide to perform a test in which only one test case is used, possibly repeated, it is more correct to define it as "individual test execution".

The choice is therefore not accidental and this contextualization is necessary to give the correct interpretation to the description of the execution process.

4.1.1. CONSTRAINTS

Obviously, before starting a simulation or just the execution of an individual test, it is necessary to verify that some constraints and conditions are respected:

- To clarify the safety issue, it is necessary to distinguish some concepts.
  A directive is a general wording in the field of safety. The directives come into effect in individual countries within the EU that decide to incorporate these into their national legislation. In each EU country, a law or provision refers to the relevant EU directive and thus elevates it to the status of national law.
  The safety objectives formulated in the directives are specified more precisely through standards. They have no direct legal relevance until they are published in the Official Journal of the EU or mentioned in national laws and regulations. However, a standard can acquire the “presumption of conformity.” This means that a manufacturer can assume that he has satisfied the requirements of the corresponding directive provided he has complied with the specifications of the standard.

The directive that regulates the use of machines installed within the European community is the EU Machinery Directive 2006/42 / EC. It aims to ensure that the machines are designed and built to be safe during all phases of their life cycle, minimizing risks for people and the environment. This Directive, with its related Standards, defines the essential requirements for health and safety (EHSR) in the following order:

• eliminate or minimize the risks as far as reasonably foreseen considering the aspects related to safety during design and construction;

• apply the necessary protective measures against risks that cannot be eliminated;

• inform users of persistent risks even if all protective measures have been adopted, specifying any necessary requirements for personnel training or protective equipment.

With the aim of complying with the directive, Robot manufacturers and those who decide to develop an application with these machines can follow the standards.

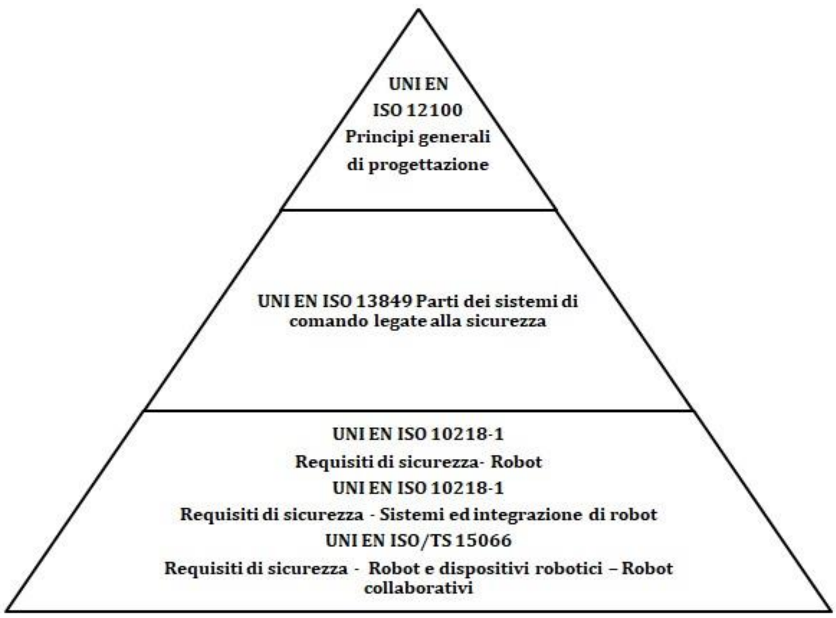


Figure 4-1 Main regulations involved in the regulatory process of collaborative operations

The main regulations on robotic matter are listed in the lower part of the pyramid.

UNI EN ISO 12100 refers to all types of machines and provides a guide for the assessment and reduction of general risks.

UNI EN ISO 13849 provides safety requirements and a guide to the principles for the design and integration of parts of machine control systems that are assigned to provide safety functions are called safety related control system parts and can be consisting of hardware and software. It does not specify the safety functions or performance levels to be used in particular cases, nor does it specify the design principles of the products that are part of the control systems.

The last type of standard involves 2 regulations, UNI EN ISO 10218-1 and UNI EN ISO 10218-2, plus a recently formulated specific guideline, UNI EN ISO / TS 15066 referring to collaborative operations.

This group includes specific types of machines and these are industrial robots with their safety systems. To make a distinction between the three documents: the first UNI EN ISO 10218-1 refers

to robot manufacturers, the second UNI EN ISO 101218-2 concerns those who decide to apply robots in a certain process, while the third UNI EN ISO / TS 15066 refers only to applications in which there is collaboration between man and robot.
In addition to these which are the main reference regulations, it is also important to mention the following:

- EN ISO 13850, Emergency stop function - Principles of design;
- EN ISO 13855, Positioning of protective equipment as a function of the approach speed of parts of the human body;
- EN ISO 13857, Safety distances to prevent the reaching of dangerous areas with the upper and lower limbs;
- EN ISO 14118, Prevention of unexpected start-up;
- EN ISO 14119, Locking devices associated with guards - Principles for design and selection.

So, according to the standards, the robot handling area must necessarily be safe: no object or person must be in the proximity of the machine or, at least, must not obstruct the trajectory of the laser scanners. In or near the car only one operator, equipped with the UOMOMORTO device, is allowed to enter the passenger seat since during the process only the collaborative robot R29 enters the passenger compartment and works at an even lower speed, therefore safer, than the nominal one; another operator can have access to the area but only near the workstation terminal, sitting or standing, as long as they have immediate access to the HMI of the robots, the power supply and the TP5 and ZSM. Remember that in the event of an emergency or danger for the operators or the car it is necessary to press the "mushroom" to stop the movement of the machine.

- The Dexterity software must be configured correctly: first of all on the HMI of PLC it is necessary to check that the robots are set in automatic mode, then they must be placed in STAND BY if they were not in that configuration previously, finally give the DRIVE ON and then FORWARD command, provided that the indication of the laser scanners and the cobot sensors give a positive signal (in green).

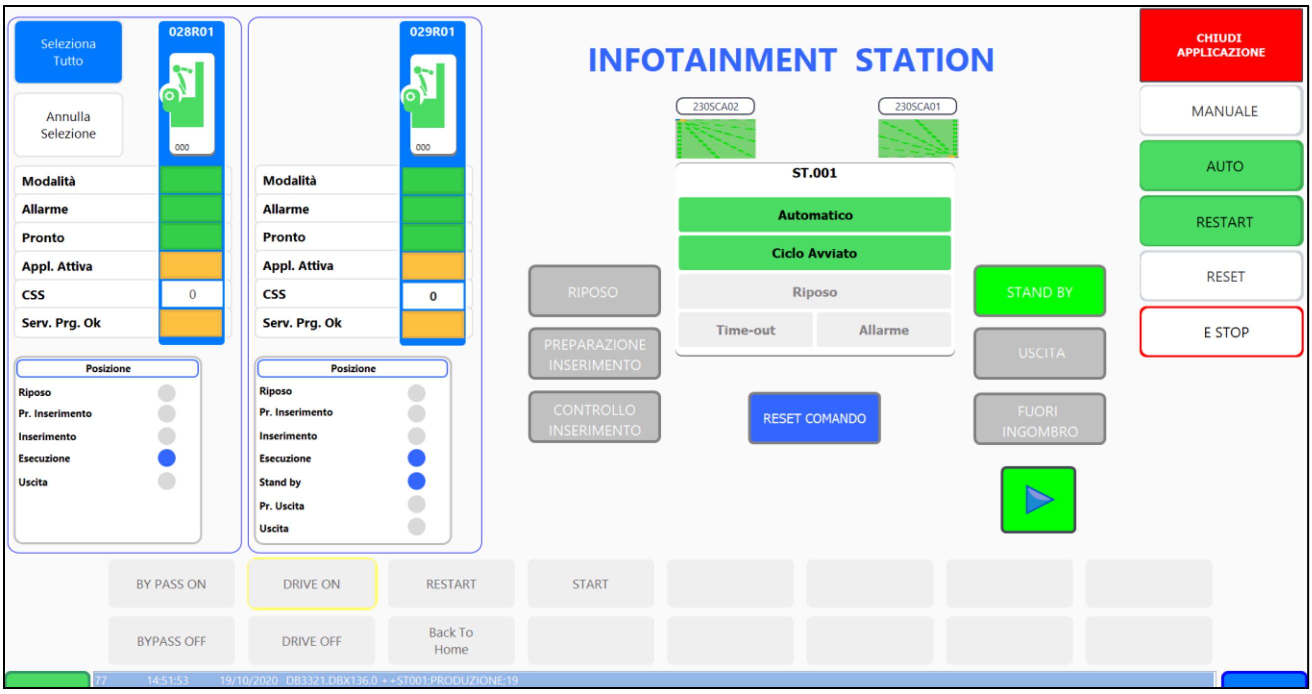


Figure 4-2 HMI - ready to start execution

At this point on the Dexterity TAB Configuration it is necessary to check:

- test connection of robots
- test connection of the chambers
- correct path configuration for NI Veristand
- correct selection of calibration files
- correct selection of active components during execution

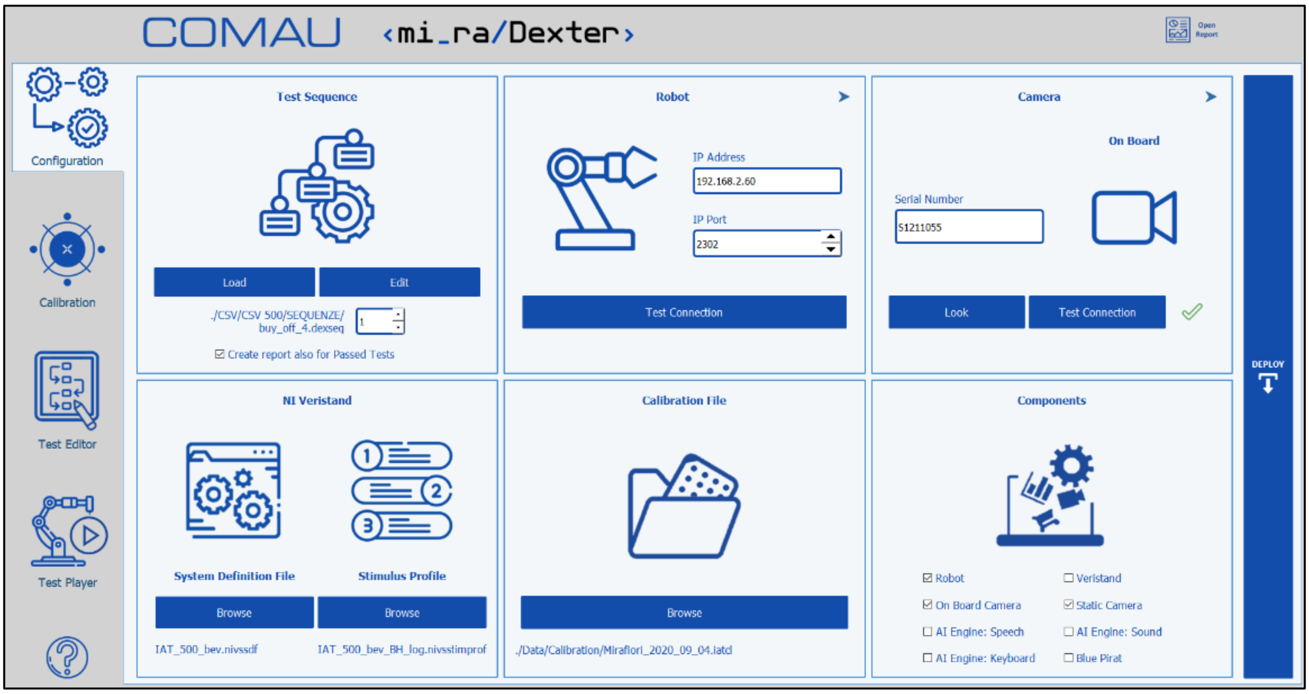


Figure 4-3 Example of TAB Configuration ready

- Finally, you need to load a previously saved sequence or edit a new one; at this point, by pressing the DEPLOY key, the machine is in effect ready to run and, automatically, you pass to the Test Player where the simulation is started.

4.1.2. EXECUTION

In the Test Player, in addition to START the execution, it is also managed, albeit limited, by means of the PAUSE, RESUME and UNDEPLOY commands, but above all the monitoring of the processed operations, which takes place in two ways:

- on the left, scrolling of the displayed actions of the test case simultaneously with the actions of the robot;
- on the right, description of the robot action with control check (execution ok / not ok).

Thanks to these notions it is possible to describe the execution of the simulation considering the features, actions and structure model of the test case.

The simulation always starts with the alignment of the robot with the main marker, i.e. the one near the system display; the onboard camera identifies the recognition pattern only if it is in the right position, therefore with the right orientation and at the right distance.

In the next step a series of looks and moves are carried out, more or less long according to the path to follow to reach the screen designated during the writing of the test. Clearly the choice of the look type depends on how the interface is designed, whether with icons or with text strings to direct its internal path.

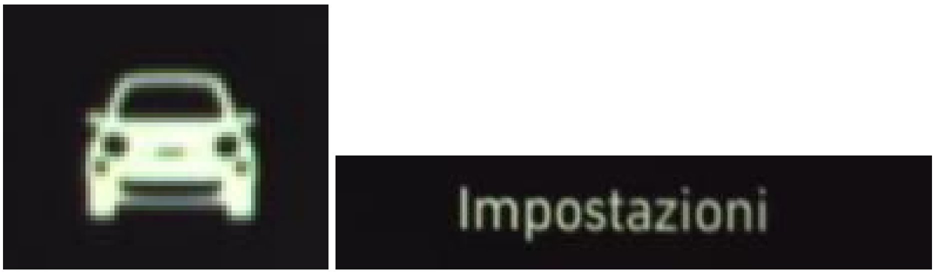


Figure 4-4 Look-image/text example

In the event that the vehicle has to be turned on or a reboot is expected, the action look-blackscreen is also used, which allows you to check the actual switching on of the display.

It is clear that action looks are a first tool for checking any anomalies as they are exploited:

- for a subsequent action if and only if the objects they have searched for and recognized by the vision system of the onboard camera are present in the interface, so if an object is not found or recognized, the subsequent action loses its feasibility potential and the simulation (or the test) fails automatically;
- alternatively, to set a binding condition directly on them.

The move actions are therefore, in general, dependent on a previous look and on the correct execution of the same and / or on the correct setting of the offsets considering the dimensions of the display (or of the length in case of swipe); only the move-programs are totally independent actions. If it is not possible, for the reasons described above, to perform a move, the test fails automatically.

As described in the previous chapter, the moves, the look-keyboard and the reproduces modify the state of the system; as far as moves are concerned, in the case of using offset, it is important to verify that the point sought is actually reached. Here the execution is absolutely necessary for the optimization of the writing of the test cases, as only through the experimentation in the car can the correctness of the measurements be ascertained.

Once the state of the system has changed, the actual control phase begins, all the actions designated to monitor correct execution are carried out in this phase:

- veristand activates the communication data acquisition instrumentation for reporting purposes; it can also intervene by modifying certain signals of the intravehicular network.;
- the store and compare actions instead exploit the visual output of the display to carry out the control in two ways:
- comparing an acquired file with a pre-existing one;
- acquiring a file before the modification of the system state and one after, comparing them subsequently to the second acquisition;
  to perform the check, the conditions on compare are imposed;

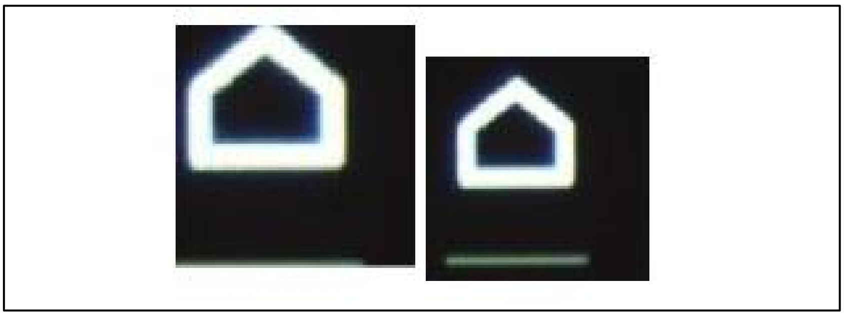


Figure 4-5 compare-image example

- listen checks sound signals coming from the radio / media, from the navigator, from the settings or from the VR; control is generally imposed by placing conditions on the action itself.

If the checks find any bugs or errors, generally the execution stops since the failure condition is set; the analysis of the anomalies is carried out at the end of the test, at a later time through the reports. If, on the other hand, the checks do not find any anomalies, the simulation proceeds to the end, with the system restoring to the initial state, if required.

To have a summary analysis of the execution and to have a quick access via link to the reporting software, there is a section on the Test Player in which, at the end of the simulation, it is possible to view the above information.

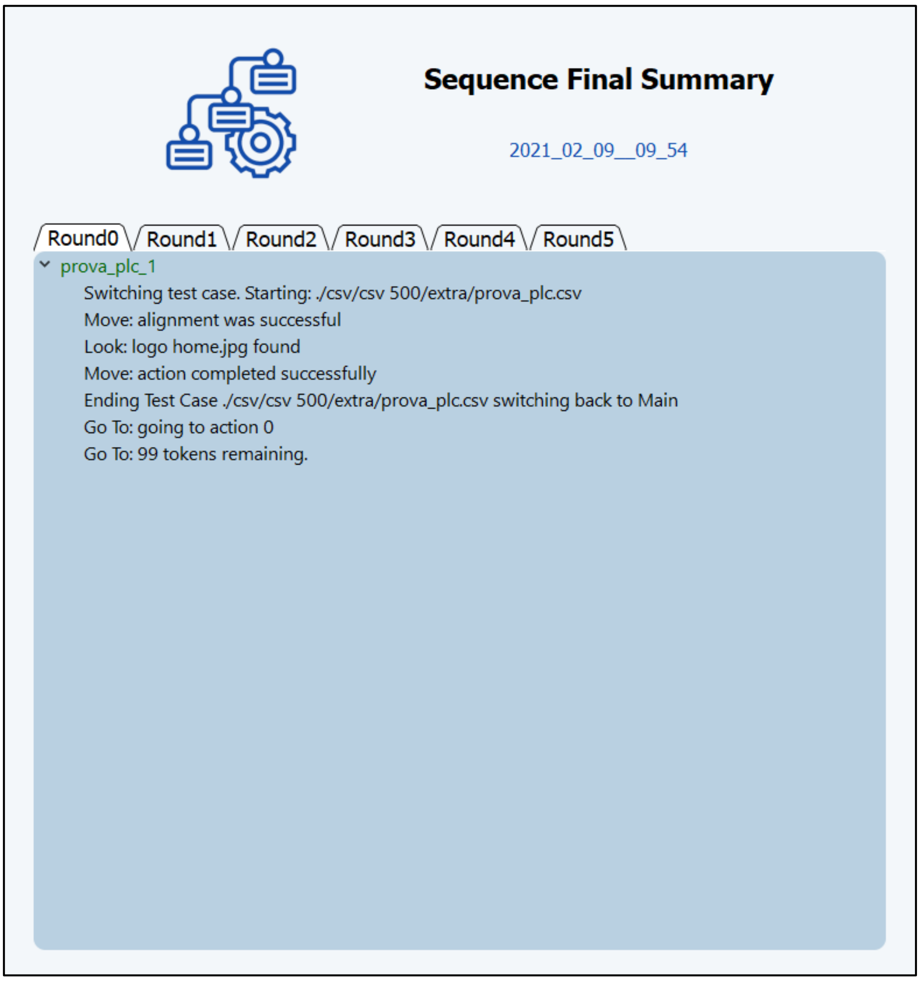


Figure 4-4-6 Execution Summary

At the end of the execution, if it is necessary to perform another one in succession, the robot remains in the STAND BY position otherwise it is preferable to return it to the REST position for safety reasons. In practice, from what has been described, the execution can be defined in a synthetic way as the physical implementation of the recurring model of the single test case or, in the case of a simulation, of several test cases.

4.2. ANALYSIS OF COLLECTED DATA

The main purpose of the application is carried out in this step: the reading, interpretation and functional use of the data obtained from the execution of the tests.

The declared objective is to obtain as much useful information as possible from each single test or simulation so that the overall knowledge on the behavior of the system can be continuously increased thanks to the discovery of unknown divergences upstream of the development. In fact, it is not taken for granted that the individual anomalies and, therefore, all the general problems of the system are dismayed by qualitative and quantitative information useful for their resolution and the acquisition of technical data in feedback from the system itself is a very powerful tool for this purpose.

However, collecting data is not enough: it is necessary that these are identifiable and catalogable in a simple and effective way in order to assign them the right priority, simply translated into rapid intervention; for this purpose it was decided to create a special report software, Diadem, capable of providing data and information that are distinct from each other and, above all, that can be engineered from internal diagnostics in parallel to internal system logs managed in collaboration by suppliers and internal engineering.

4.2.1. REPORT

The reporting is defined and interfaced through the Diadem software and stored at the level of the single test or simulation in the memory of the Dexter software: we can therefore define the first as the tool that makes the output of the second readable to the user.

The report of the execution is divided into four levels, which can be integrated with each other thanks to the temporal sequence:

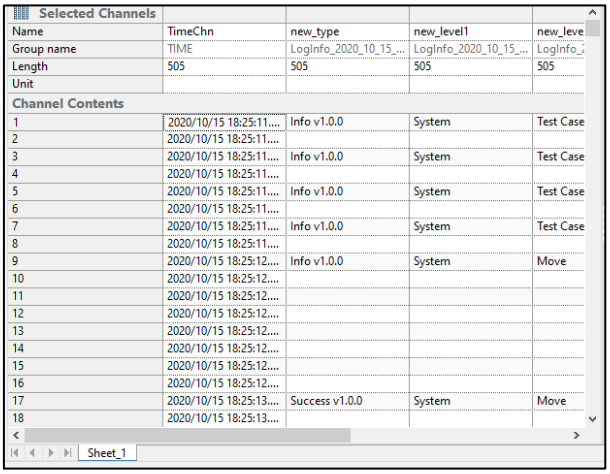
1. robot actions
2. the video coming from the static camera
3. signals intercepted by the CAN network
4. the images captured by the onboard camera

The first three are interfaced on the software screen and follow a common temporal logic based on the communication data rate between software and hardware: logging takes place for each unit of time, discretized on the data rate.

Instead, the acquired images are not directly visible on Diadem but are stored in a Dexter system folder; in this folder there are, in chronological order, the simulation / test execution folders: these contain the link to the Diadem report of the execution to which they refer and the folder of images above.

All useful data are therefore easily traceable and extractable as they follow a well-defined standard.

The logging of the robot actions is basically the time history of everything that the robot has performed in the test / simulation. Starting from the alignment up to the undeployment action, everything is recorded and defined by the software with a temporal location identified from start-execution-conclusion: a time interval is therefore identified in which the start of the action corresponds precisely to the instant of the test in which the action was actually performed.



Selected Channels				
Name	TimeChn	new_type	new_level1	new_leve
Group name	TIME	LogInfo_2020_10_15_...	LogInfo_2020_10_15_...	LogInfo_
Length	505	505	505	505
Unit				
Channel Contents				
1	2020/10/15 18:25:11....	Info v1.0.0	System	Test Case
2	2020/10/15 18:25:11....			
3	2020/10/15 18:25:11....	Info v1.0.0	System	Test Case
4	2020/10/15 18:25:11....			
5	2020/10/15 18:25:11....	Info v1.0.0	System	Test Case
6	2020/10/15 18:25:11....			
7	2020/10/15 18:25:11....	Info v1.0.0	System	Test Case
8	2020/10/15 18:25:11....			
9	2020/10/15 18:25:12....	Info v1.0.0	System	Move
10	2020/10/15 18:25:12....			
11	2020/10/15 18:25:12....			
12	2020/10/15 18:25:12....			
13	2020/10/15 18:25:12....			
14	2020/10/15 18:25:12....			
15	2020/10/15 18:25:12....			
16	2020/10/15 18:25:12....			
17	2020/10/15 18:25:13....	Success v1.0.0	System	Move
18	2020/10/15 18:25:13....			

Sheet_1

Figure 4-7 Robot actions logging

These clarifications are necessary to specify the context in which this type of logging must be inserted, i.e. software debugging: the ways and times in which the robot moves and acts are essential checks for software developers to plan for any changes or improvements; they also serve the user to perform a visual check of correspondence between the video images coming from the static camera and the actual robot actions and movements.

The video recorded by the static camera is instead a specific request of the company to meet the need to provide the analysts of the issues in the Iman environment also with a visible confirmation of the anomaly; it can also be of help to the user to search for possible improvements and optimize the drafting of the test cases after the execution.

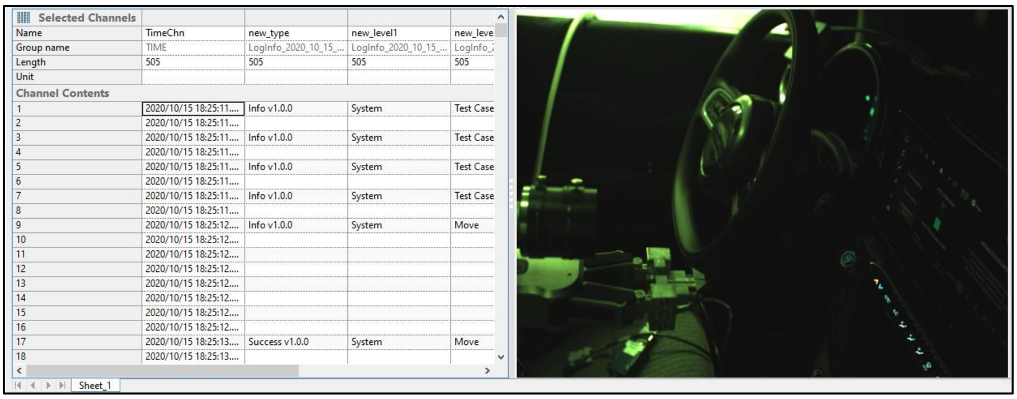


Figure 4-8 Static camera logging

As for the images acquired by the onboard camera, such as the videos of the static camera, they are very useful data for issue analysts and for the user for the correction and optimization of test cases; they are also indicative data for Dexter software developers for the detection of any errors and correction of the programming or of the vision algorithm.

All these operations are performed automatically by Dexterity and the user will see just the window inside DIAdem. The report is easily navigable and no particular knowledge of the software is required; moreover thanks to the *Open Report* menu, it is possible to navigate through reports of old test

Finally, the Diadem interface is almost entirely dedicated, i.e. for the remainder, to the analysis of the signals coming from the vehicle's CAN network that are often a relevant request from Diagnosis Engineering, in parallel with the internal system logs. The internal system logs are not included in the Diadem report but are in any case automated with a specific default test case which enables their acquisition by the robot if the test execution fails.

4.2.2. DATA FROM CAN NETWORK

As mentioned in paragraph 2.3.1. the vehicles in the RG fleet are equipped with special instrumentation for the acquisition of signals from the CAN network; the equipment is supplied by Control Tec (Aptiv) and is present on all vehicles since it has been identified as a reference for a series of advantages:

- compactness and ease of installation;
- specific button for the acquisition triggering and consequent sending of the extracted data in a time interval close to the instant of the triggering (connectivity/telematic service);
- known and acquired coding as lesson learned;
- cloud.

Figure 4-9 Control Tec logo

However, as regards the robotic application, Comau has agreed with the Quality management to use another supply and therefore another type of instrumentation, albeit equivalent in functionality: National Instruments does not limit itself to supplying the reporting software (Diadem) but the sales package also includes the aforementioned instrumentation, namely the CompactRio.

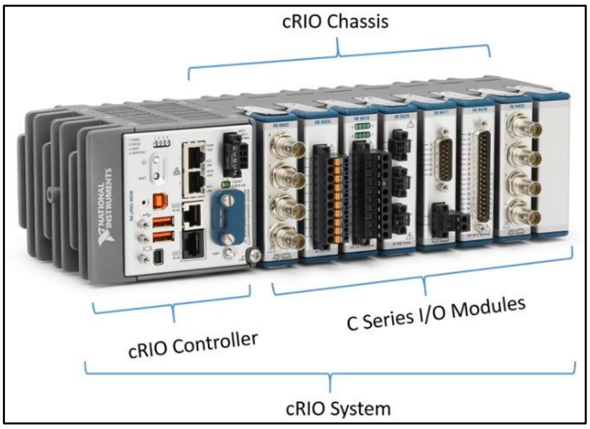


Figure 4-10 CompactRio system

To better define it, CompactRio is a user-programmable controller with a processor and a FPGA (Field-programmable gate array, an integrated circuit designed to be configured by a customer or a designer after manufacturing), populated with one or more I/O from NI or a third party. These modules provide direct connectivity to sensors and the network, plus they enable advanced features. It therefore represents the hardware of the reporting and analysis package that National Instruments supplies to Comau.

The choice to rely on National Instruments rather than Control Tec in this case is dictated by the fact that the Diadem software is perfectly compatible in terms of interface towards Dexter and this represents a fundamental aspect in the approach and learning of the customer / user of the platform.

The importance of data acquisition from the CAN has multiple implications: by reading the signals coming from certain sensors or actuators it is possible to generate a signal conditioning as an immediate response to the reading or a simulation of or the simulation of a certain behavior of the vehicle under specific conditions; this is possible thanks to two specific factors:

- the first is the possibility of using veristand programming (therefore Dexter) which allows to acquire and simultaneously analyze the signals;

- the second is the programmable modification of the FPGA which allows the physical realization of the conditioning.

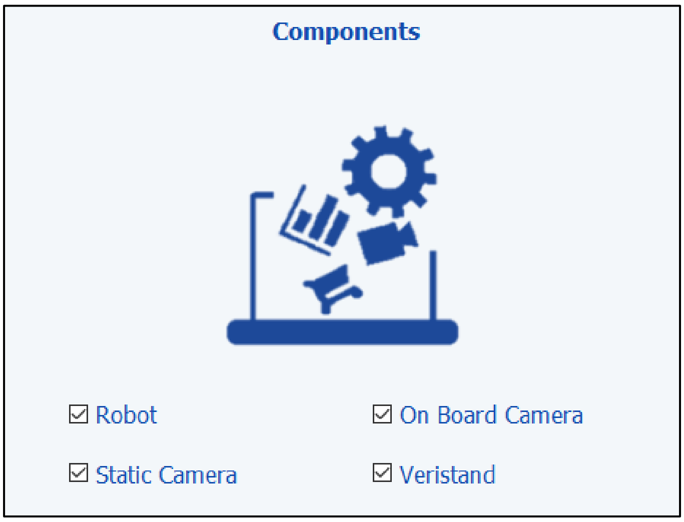


Figure 4-11 Veristand 1

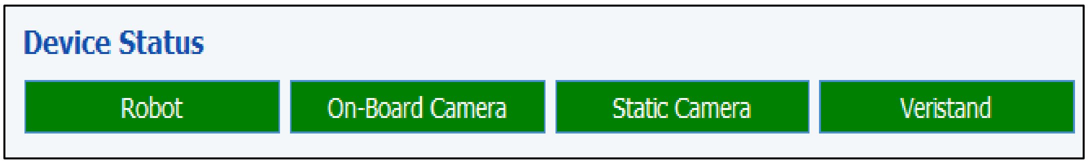


Figure 4-11 Veristand 2

It also clearly appears to be the most important aspect of reporting as the provision of "engineerable" data probably linked to anomalies is the focus of the entire application.

In detail on Diadem it is possible to display a drop-down menu in the interface in which all the network signals are cataloged and selectable; they are divided into macro categories inherent to the main sections into which the CAN is divided: the one of greatest interest for the application and, essentially, the least complex as it has a lower data frame (125 kb/s) and characterized by event signals is certainly the BH section (the other sections are instead characterized by a data frame of 500 kb/s and for the transmission of constantly sent performance signals).

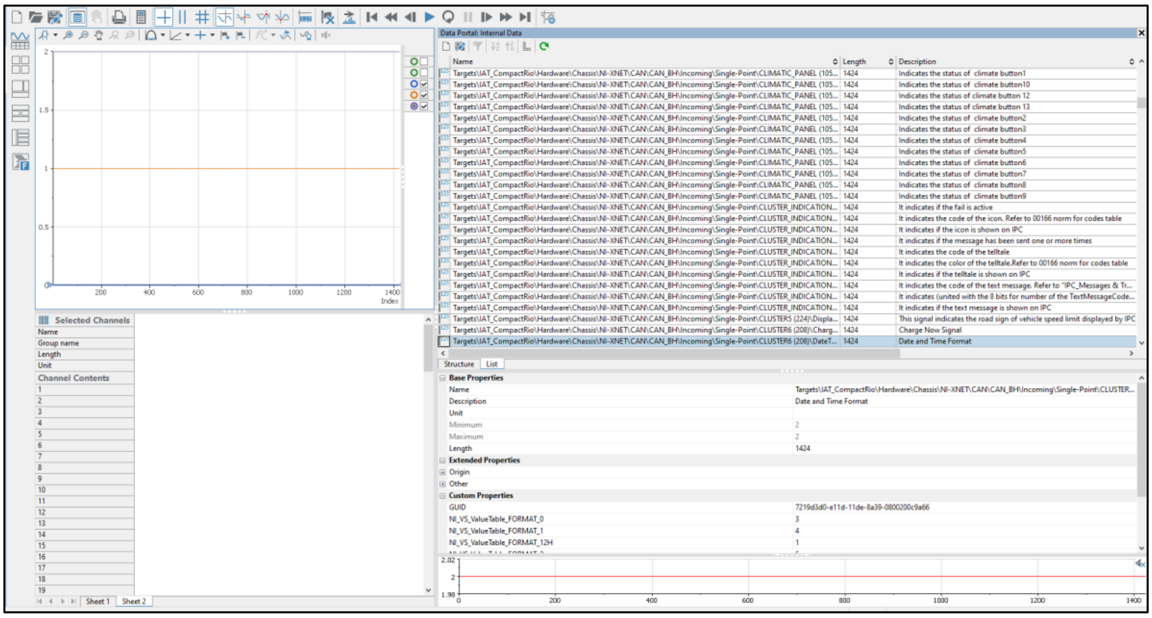


Figure 4-13 CAN signals

Section BH of the CAN contains all the information signals on the status of the systems and components of the car, with reference in our case, to the infotainment. After conducting a test by activating the acquisition with Veristand and enabling the National Institute server, the signals relating to the single sequence performed are logged and stored independently in the reference report of the above sequence.

Knowing in advance which system state the signal code refers to and the definition of the states based on the event, it is possible to analyze the behavior of the system under certain operating conditions; moreover, by exploiting the functionality of the Diadem interface, it is possible to limit the events to a specific sub-interval of time by attaching the video and robot logging as a reference, as described in the previous paragraph.

This methodology therefore allows to provide very accurate and reliable diagnostic data from different points of view, thus making testing a less dispersive and more timely activity and catalyzing in a single completely automatic step a process that is otherwise manual and over several steps.

Upstream of all this it must be specified that for the acquisition from the CAN network it is necessary to bypass or disable the safe gateway (aka SGW) of the car through the use of an internal company software, the Dianalyzer, which, as a diagnostic tool, allows the access to the network for a time determined by a maximum number of key cycles, specifically 255.

In the diagram and image below the overall methodology and the software architecture are synthetized.

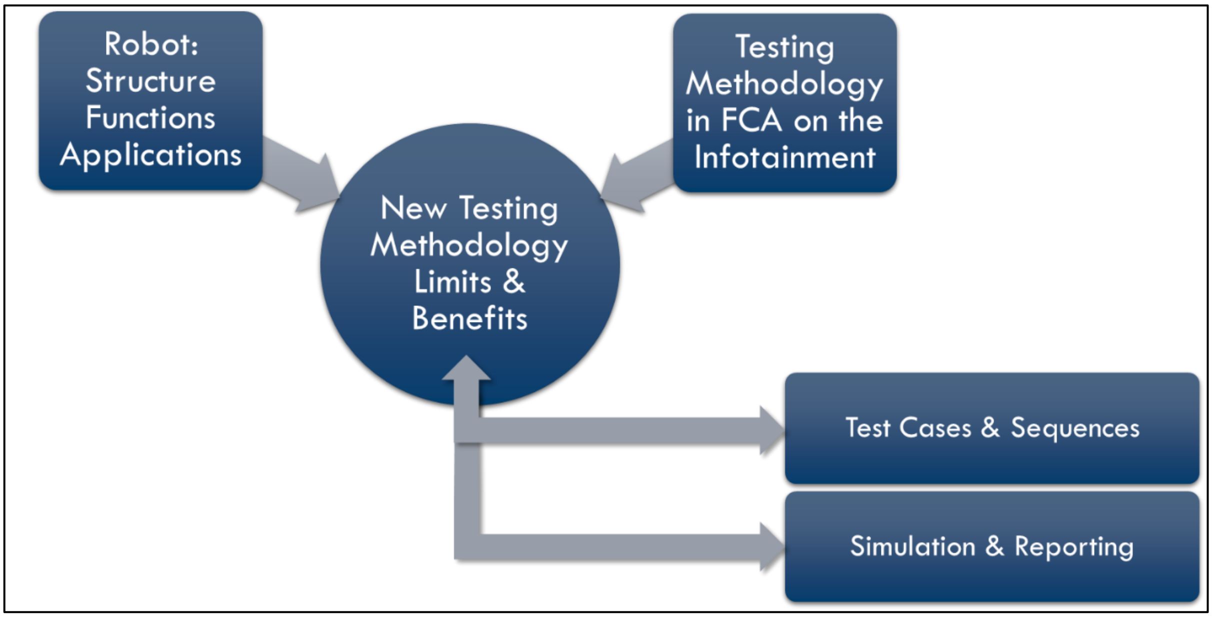


Figure 4-12 Diagram of the methodology

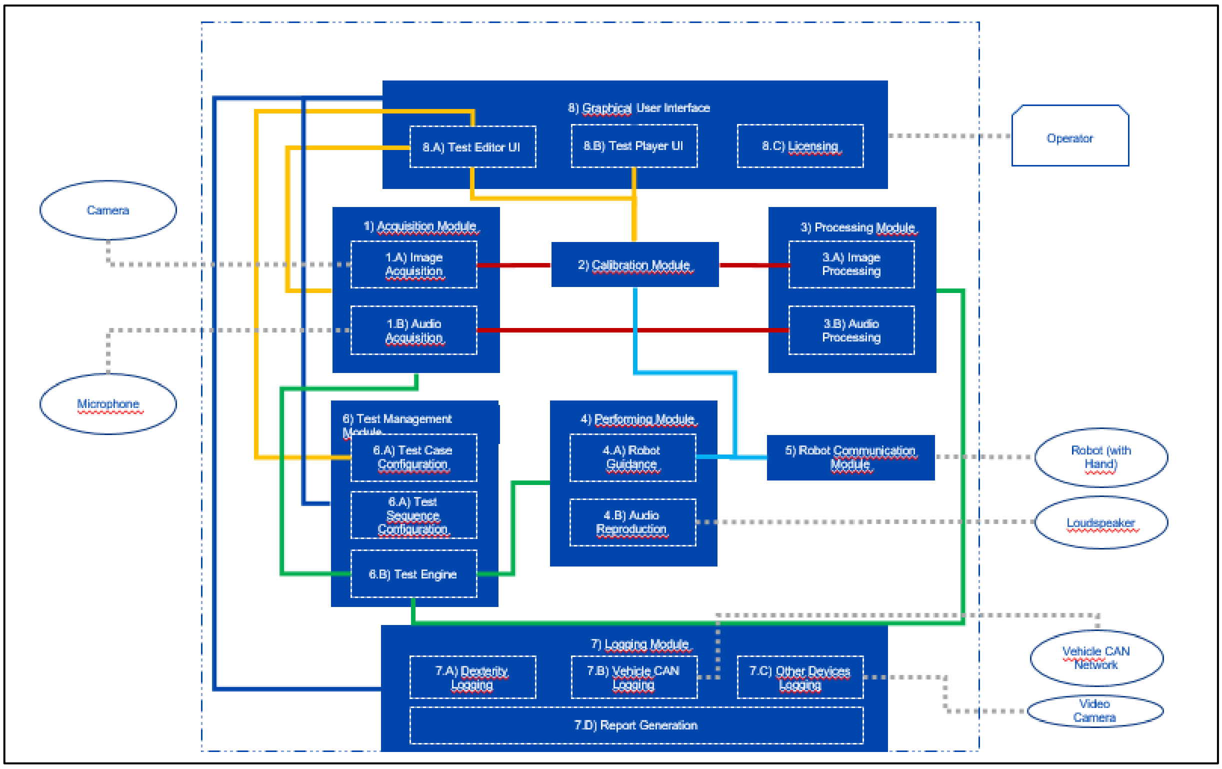


Figure 4-13 High level software architecture

5. SUPPORTING BY THE REFERENCE BODY AND SUPPLIERS

This chapter deals with how the project was followed and supported by the reference body, specifically Infotainment Quality, and what activities were carried out in order to obtain comparative data that would enhance the benefits and highlight the limits and reach right level of knowledge and experience for optimal use.

Then we discuss the importance that the supplier-customer relationship established with Comau has had in the development and implementation of the platform in the Mirafiori plant.

5.1. SUPPORTING BY INFOTAINMENT QUALITY

Figure 5-1 FCA Quality EMEA

5.1.1. START OF THE PROJECT

As described above, the robotic platform is located in the Infotainment Bench Area and is managed and controlled by the Infotainment Quality body. Consequently, the notions and information useful for the complete knowledge of the project were provided as a first input by the personnel of the aforementioned division: the variety of subjects, the technical characteristics, the features and functions, the integrated systems and the communication protocols that the infotainment system has with the outside were the foundations for understanding, not only the object of testing, but also of the development that the project should have achieved; moreover, the understanding of the traditional testing methodology, starting from the internal regulations, passing through the knowledge of the checklists and the modus operandi of the specialists, the acquisition standards and the issue management methods, was of primary importance for the training project.

Following a specific request for Infotainment Quality, it was decided to develop the platform using no longer, as previously established, the Alfa Romeo Stelvio, but a 500 BEV, given the contingency of the validation of the latter product; in particular, the choice of a car fitted with the R1 High pre-production environment system was not accidental as it was representative of a very significant laboratory object at that stage. Unfortunately, due to unexpected delays on the closure of the site, they did not allow to exploit the potential of the platform for the validation of this product but the results obtained, although in retrospect, were satisfactory.

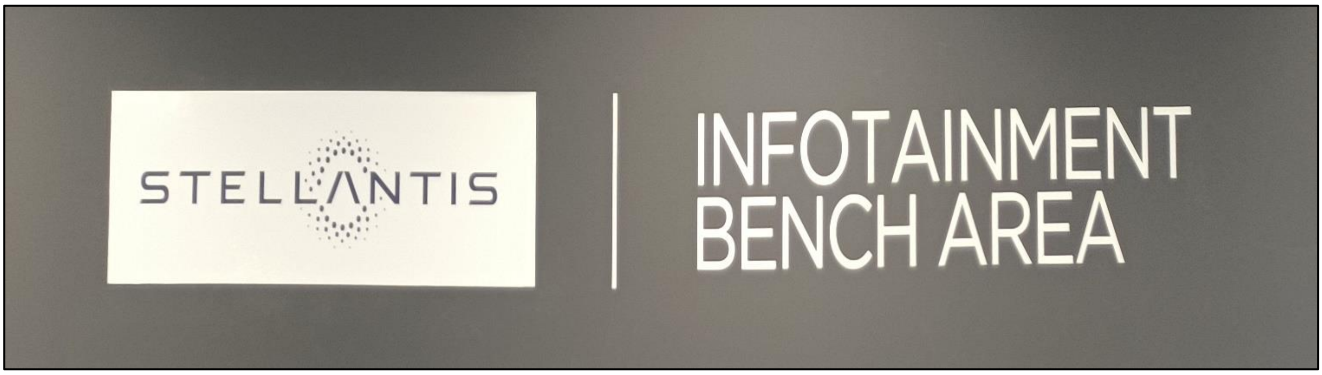


Figure 5-2 Infotainment Bench Area

5.1.2. DEVELOPMENT

As described in chapter 3, the construction of a database that contained the testable functions of the R1H system on 500 was the starting point for the execution of the project from a company perspective: Infotainment Quality, in addition to making the vehicle dedicated to the platform available, allows specialists to have even the cars of the RG fleet available for a limited time slot so that any comparison and an even more in-depth study on the system can be conducted: only thanks to the continuous and profound use of these cars and their systems is It was possible to compile our database in the best possible way, making it, although specific to a single type of vehicle-system integration, flexible also in the direction of other vehicle-system pairs.

In any case, in order to know further for the purposes of the robotic application the subject of the testing in question and to learn the methodology for inserting anomalies on IMAN and the management in collaboration with the RMs, Testing Management was also carried out in RG; this activity was of considerable inspiration for a more in-depth dissection of the system and prioritization of the main issues that can be faced during testing.

Due to some legitimate delays in the development and validation phase of the project, especially due to the resolution of problems related to the security of the platform, the actual use of the same began after a few months in which the change from the car was arranged: from VP 107 (PRE PROD environment infotainment software), whose software has come to full maturity, to PS60 (PROD environment infotainment software) which had a software still under development and therefore more significant for testing.

The first practical verification of the potential of the platform requested by the body was a direct comparison between checklist 28, i.e. infotainment system test, performed by the drivers rather than automatically thanks to the robot drawing from the executable test database: this comparison was very important as a source of qualitative and quantitative data useful to be analyzed to define the performance of the platform with respect to manual testing by driver.

The crucial activity carried out to determine the contribution of the platform in quantitative terms was the comparison in the identification of anomalies with the testing specialists; the main difference that could be found lies in the fact that the activity that the specialists carry out is that of a real search for the anomaly, concentrating and dissecting in detail the functionalities of the system in its contents and most critical interactions, in particular those of integration with devices external to the system itself or of communication with the environment in the various protocols.

On the other hand, the platform plays a more targeted role at reproducing certain conditions, it simulates a very stressful use for the system from a customer perspective and on the research side it works in a more random than selective way, but, it is important to underline, in quantitative terms the anomalies found are in considerable numbers and with a high frequency.

The final part of the project, on the other hand, consisted in the exchange of data and information useful for developing a quantitative and qualitative analysis of the use of the platform in relation, not only to the identification of the main characteristics and useful functionalities of the latter within the plan strategy of the Infotainment Quality body, but also by comparing the performance of the platform itself with that of a specialist, obviously normalizing the output data to the number of operating hours. Furthermore, some requests for ad hoc tests on certain system functions have been formalized (see Alexa in Vehicle and VR multilanguage operativity).

5.2. SUPPORTING BY COMAU

The relationship with Comau was the basis of all the initial development and initiated the feasibility of the project.

Figure 5-3 Comau supplier mission

5.2.1. START OF THE PROJECT

First of all, at the start of the project it was established bilaterally what the characteristics and functionalities of the product would be: starting from the idea of the robotization of an unprecedented process such as automotive testing, it was necessary to establish how the machine should be structured to meet the needs of FCA as a customer.

The prerequisites and prerogatives mainly required are based on three fundamental principles:

- the use of the platform by an operator not necessarily expert in robotics and programming
- flexibility in the variety of vehicle products tested
- the possibility of leaving the layout and structure of the installation space unchanged

To meet these needs, Comau has decided to pursue an enterprising development path, both as regards the hardware and software components.

From the hardware side, the choice fell on the use of a machine composed of two robots, which have been fully described in chapter 1; this position is motivated by the fact of making possible for a collaborative robot to enter the car independently from the model in an extremely precise manner and, at the same time, maintaining the internal and external layout of the tested product unaltered. The other possible solutions conceived each involved either a modification of the equipment of the vehicle or an excessive and expensive modification of the workstation layout.

Furthermore, the equipment of the platform that is inside the vehicle (static video camera, CompactRIO acquisition unit and relative wiring) is easy to place and does not create particular encumbrances or important inconveniences for robot or operator handling.

As far as the software component is concerned, the creation and optimization of Dexter's metalanguage was of absolute importance: making a non-trivial language such as robot programming, simple and usable for an average user was not a foregone conclusion, however the Comau engineers they have succeeded in the enterprise and have also been of considerable help and support in learning the metalanguage.

The development of the platform also saw the use of tools that allowed the exploitation of artificial intelligence applications as crucial points and their tuning was a valuable finishing job by the engineers. The integration of the robotic cell, software, artificial vision and voice recognition tools, monitoring and control instruments is the perfect synthesis of Industry 4.0 implementation in a new process and has seen a considerable effort by Comau in the development phase.

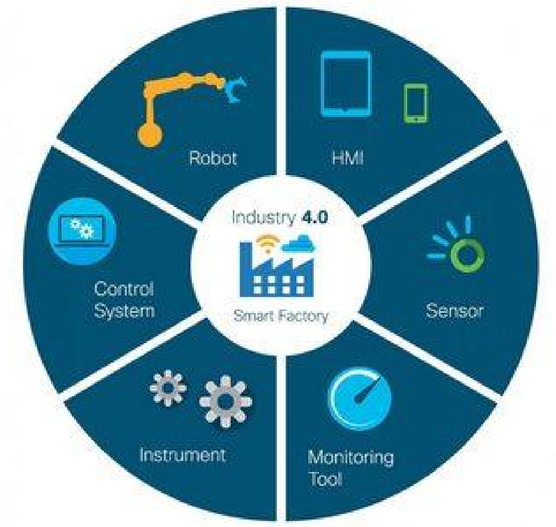


Figure 5-4 Robot 4.0

5.2.2. START UP & FOLLOW UP

During the start-up phase of the platform, before the closure of the project and the buy-off, Comau provided transversal support:

1) technical;
2) training for users;
3) logistical and aesthetic as regards the appearance and composition of the workstation.

On the technical side, Comau constantly took care to update the supply and bring it to the final and optimal state; both hardware and software updates have been made. In fact, when the cell was installed in the Infotainment area, the machine was not in the final state: first of all the Small robot, although integrated with a fully collaborative software, at the hardware level it did not perform this function as the final component was at that moment under development and validation; at the end of this process, the Comau team took care to install and configure the cobot within the system in the best possible way. The limitations imposed by the EU Machinery Directive 2006/42 / EC, in particular the UNI EN ISO / TS 15066, have highlighted problems in terms of performance related to safety that are not sustainable and therefore unacceptable; to cope with this occurrence, Comau has compensated with the supply of additional safety devices (the third laser scanner and the Deadman device) embedded with new security protocols at the software level, restoring the required level in terms of performance and guaranteeing the standard of safety required by the legislation, also reaching a further application step by adding the possibility to the machine to work even in the absence of an operator during the automatic execution of the tests. Thanks to these interventions, CE conformity certification, a precise risk assessment and the green light from the company SPPM following the final buy-off and closure of the construction site were obtained.

During this waiting phase, as described above, a car change was arranged so a significant new calibration of the robots was necessary, furthermore tests had to conducted: in this cases too, Comau's support was essential to guide FCA personnel through a correct procedure and an optimal result as concerns the calibration and to help in conducting test .

A basic training was organized and integrated into the sales package and a further one was agreed between the managers to make the user an independent one in terms of robot manual handling and calibration.

Figure 5-5 Comau course

In terms of logistics and aesthetics, Comau was responsible for providing a wooden cover, made by external suppliers (tier 2), which covers and protects the base of the Big robot, the wiring, the electrical cabinet and the control boxes; inside the workstation, in addition to the PC terminal, there are also two monitors, one on each side of the cover: the first, on the car side and then in the area for professionals, is the interface with the software for user, the second, on the external side of the cover, is the interface for visitors.

Figure 5-6 Cover lateral side

Finally, following the buy-off and, subsequently, supplying the definitive version of the machinery, Comau has completed its development and implementation work but continues to provide support in terms of maintenance and technical advice.

6 CONCLUSION

In the final chapter the final considerations drawn and deduced on the current use of the platform and the forecasts on any new or extended methods of future use are discussed.

The technical and functional limits and benefits that the platform and its application present are initially described; the use and any developments that the company will carry out in the near future in conjunction with a plan for the long-term future are described below.

6.1. LIMITS

The machine in its structure and configuration, both hardware and software, and the application in the testing process on a problematic system in some respects, is generally subject to limits of use, for technical reasons or functional aspects.

6.1.1. TECHNICAL

As for the technical side, the main limitations are identified in:

- Structure

  The structure of the platform is characterized by considerable dimensions and a very high weight; the dimensions of the car to which they must be added: the area reserved for the cover which, remembering, contains wiring, electrical cabinets and control boxes, and that reserved for the car, which it is advisable to keep in a fixed position for the entire duration of the process of testing. Furthermore, the area identified by the calibration of the laser scanners must also be considered which, for reasons of personnel safety (high priority), must be dimensioned in a conservative way, therefore reasonably extended.

  It is evident that the workstation area assumes considerable extension which in not all industrial environments can be easily replicated.

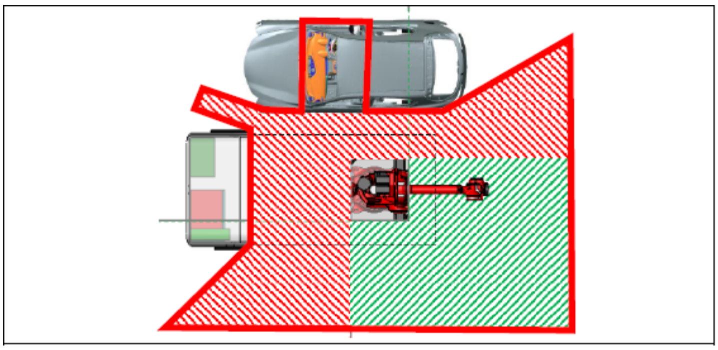


Figure 6-1 Robot handling area

The ceiling height must also be considered as the vertical extension of the joint robots reaches 4 meters and even in this case not all environments are suitable.
The weight of the machine, on the other hand, imposes extreme safety constraints as in its dynamics it runs the risk of damaging objects or people in a serious or even irreversible way.

- Work environment

From the considerations made regarding the structure it is clear that the work environment must necessarily respect considerable dimensions; for this reason it is difficult to recreate it ad hoc or exploit, for example, isolated garages and the only industrial environments to contain it are characterized by even larger dimensions, with areas at least an order of magnitude larger: this risks compromising the isolation of the area of testing both in terms of safety and functional and it is therefore necessary to take precautionary measures in this regard.

6.1.2. FUNCTIONAL

The most important limitations emerge in the functionality: the machine is not able to perform some operations that the human being would be able to do and this is obviously taken for granted; however these limits are not dictated by a lack of "smartness" of the machine or of those who programmed it, but rather by factors and constraints that go beyond the powers of the aforementioned subjects.

In the first analysis, the greatest functional limitation lies in the impossibility of performing dynamic tests: for obvious reasons the car must remain absolutely in a static position during the test. The robot is fixed outside near the vehicle and clearly cannot move with it; the choice of fixing the robot to the outside is dictated by the fact of testing the vehicle in the configuration in which it is presented to the customer, therefore without absolutely modifying the layout and to respect this need the solution chosen is the above.

Another functional limitation is the need to perform calibrations for each movement of the car or replacement of the latter with a different one. In this case we are dealing with an intrinsic problem of automation and traditional robotics: the artificial subject is not able to establish a priori the absolute and relative positions.

Another important aspect is certainly the impossibility of performing some actions or tests; in particular, speaking of actions, reference is made to the fact that the listen action cannot be used because, given the high sensitivity and low tolerance of the voice recognition system, the environment in which the tests are performed is unfortunately not adequately isolated, which is why all written test cases do without it. Instead, the inability to run some test cases is essentially dictated by the limits of the infotainment system interface, both at the display level and related screens and at the dashboard level (for example the buttons on the steering wheel of the 500 BEV are inaccessible to the robot), or by limits due to the vehicle software version or, finally, by the impossibility of performing them in static mode.

Navigazione	Menù principale	Impostazioni	Premere su Suoni e avvisi

Appare una lista con le seguenti voci: Leggi ad alta voce (apre lista con voci di possibili avvisi durante la navigazione), Tipo di avviso (Visivo,audio e verbale/Visivo e audio/Visivo), In caso di eccesso di velocità (spunta), Ingorgo sul percorso (spunta), Intervallo di ricerca troppo breve (spunta), Tutor e autovelox (spunta), Avvisi di sicurezza (spunta)	Non verificabile su test statico

Table 14 Example of not functional test case

Ultimately, another missing feature is certainly the impossibility of remotely performing and controlling testing: in this regard, of course, the security component has absolute priority, but it is certainly a significant constraint as it does not allow to fully exploit the possibility of execution continuity, a prerogative of automation.

6.2. BENEFITS

The testing process of the Infotainment system was an activity that until recently was not practicable at the counter in an automated way, it required the use of multiple human resources for an activity often unknown to most, for which a certain level of specialization and long technical execution procedures, from the actual test to the compilation of the checklists to the loading of the issues on the database are required.

6.2.1. FUNCTIONAL

The realization of this project has tried to overcome the difficulties of a process that can be defined as dispersive and redundant, managing to establish a standardized methodology supported mainly by five factors:

1. testing robustness & repeatability and more accurate control (human error called out)
2. less time consuming (continuously testing)
3. the provision of data and information in adequate quantities and ,above all, accurate
4. stressing the system beyond the normal use
5. economic

It is therefore clear how the functional advantages of automation and artificial intelligence are the key points in the construction of the project and of the new process.

All this at the cost of:

- one and only one car, with a standard layout and constantly updated at the software level (clearly only one car per model of Infotainment system or line produced to be tested);
- a trained resource able to manage the platform, its functions and applications, safely and with progressive experience;
- a robotic platform and a suited area.

Therefore, in the long term, the advantages and the economic return are a considerable aspect, strategically very important, given the use of a limited number of overall resources on a very complex process.

Figure 6-2 Robot operator

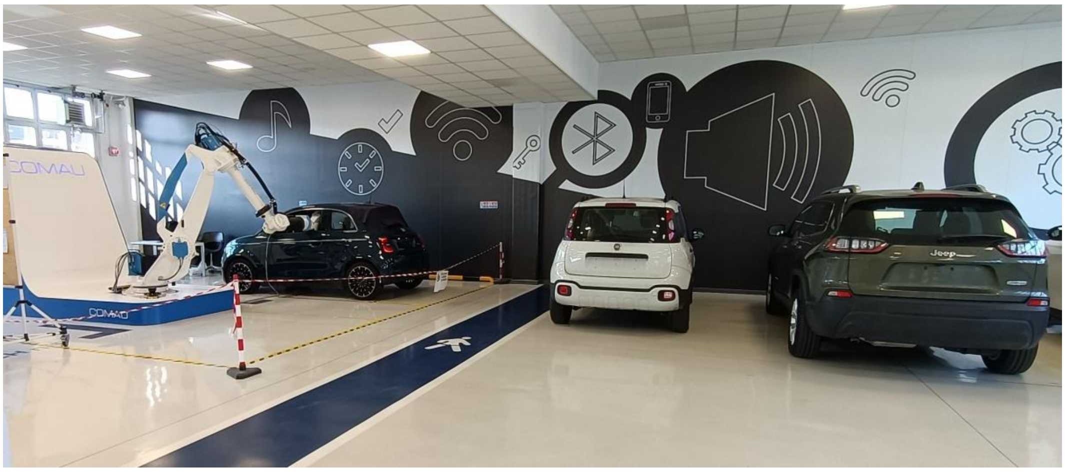


Figure 6-3 Panoramic view

6.2.2. ROBOTICS

In terms of automation, although the use of a cobot may cause a discrete slowdown in operations compared to a traditional equivalent, this allows the user to move close to the car even inside the car when it is running, under certain safety conditions: this is a very important feature for testing purposes as it frees the user from the static nature of the station and allows him to check the conduct of the test in the car as he would in the manual case, thus giving him a certain freedom of action if required and guaranteeing the possibility of maintaining or improve the knowledge of the system behavior in complete safety.

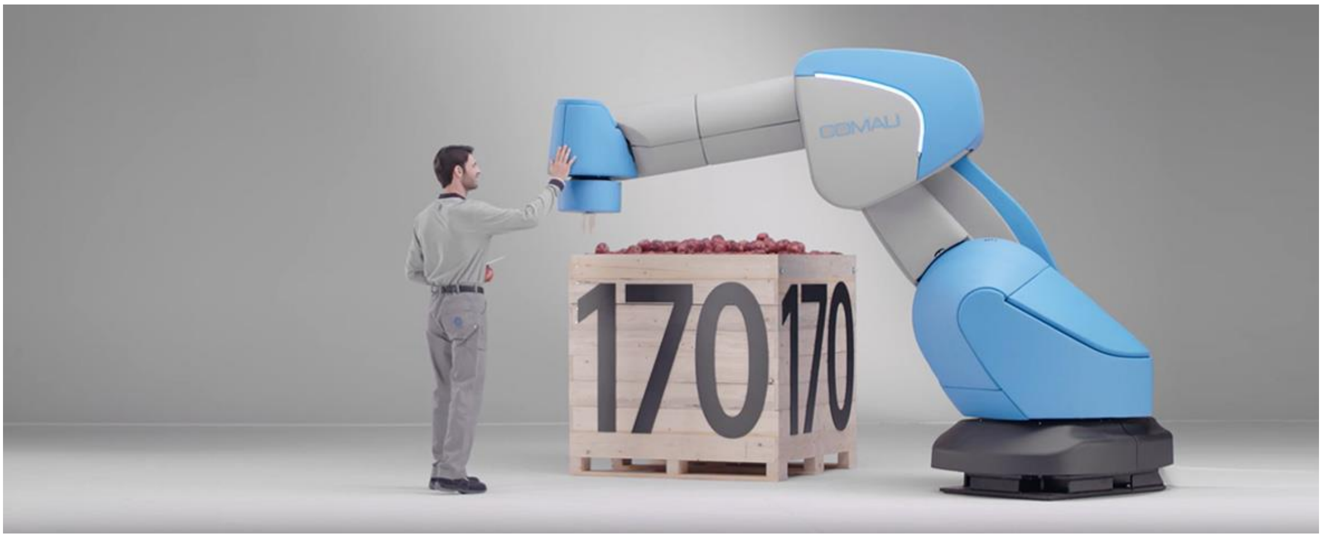


Figure 6-4 Aura: example of cobot by Comau

Finally, as already mentioned several times, the implementation of collaborative robotics and artificial intelligence with vision systems and voice recognition, increasingly projects the company in the perspective of digital&smart and Industry 4.0 and helps to improve the knowledge of this still little explored industrial horizon, also providing potential ideas for further smart applications.

6.3. COMPANY ACHIEVEMENTS

What can be deduced from the case of the project in FCA within the Infotainment Quality body in analytical terms is taken from the comparison of the data emerged with the use of the platform with the traditional data of the specialist activity.

The first point to discuss is certainly whether the robot is actually able to perform its function correctly, that is, to find the highest possible number of anomalies that can be found in the context in which it operates and, of course, adequately providing the required output data, for the analysis of the anomalies themselves.

A collection was organized to highlight the results obtained.

WEEK	ID	IMAN	TEST TYPE	TYPE	DATE	VEHICLE & SERIAL	SEVERITY	DESCRIPTION	IMPACT AREA	SW VERSION
4	1	9145	2	REPEATED CASE	26/01/2021	332 - PS60	100	App drawer icon on Status Bar: difficulty in pressing it correctly	Status bar	R16.27
	2	8992	2	REPEATED CASE	26/01/2021	332 - PS60	50	VR malfunction	VR	R16.27
	3	9335	1	NEW	27/01/2021	332 - PS60	10	Wi-Fi icon on Status Bar changed	Status bar	R16.27
	4	9345	1	NEW	27/01/2021	332 - PS60	10	Comfort Icon on the Status Bar incorrectly shows "LO"	Comfort	R16.27
	5	9363	1	NEW	27/01/2021	332 - PS60	10	Impossible to reorder stops	Nav	R16.27
	6	9045	2	REPEATED CASE	27/01/2021	332 - PS60	10	AA icon on Category Bar missing	Projection	R16.27

Table 15 Extract of Robot issues collection table

The table is organized as follows:

- week #;
- ID issue of the week;
- relative IMAN ID;
- test type (to select the type) & type;
- vehicle & serial;
- severity;
- description of the issue;
- impact area on test object;
- SW version of the infotainment system installed.

Considering that the collection actually started from 04/04/2021 (week 1) and ended on 09/02/2021, it was possible to normalize the data sample over a defined period of time and determine very interesting analytical parameters in terms of performance, real KPIs.

6.3.1. QUALITATIVE ANALYSIS

The qualitative analysis is mainly focused on three aspects: severity, impact area on test object and type. Furthermore, it must also be noted that some issues found were not then transcribed in IMAN due to errors due to inexperience in the transcription of some individual test cases or in the drafting of test sequences, in other cases due to malfunctions of the additional hardware tools supplied, such as USB pen drive.

Before reading the data, however, a clarification must be made: the validation context, i.e. the progress status of the project, was already quite mature in this time delta (just think that the 500 BEV car was already in the marketing phase from 01 / 01/2021), the tested software version, the R16.27, was therefore stable and "cleaned up" of the majority of the bugs presented in the testing phase along the previous months on the older versions.

I. As far as the severity aspect is concerned, for the above reason, as can be seen from the table and the graph, most of the anomalies counted are of low severity: this is clearly the characteristic most influenced by the status progress of project 332.

Severity		
L1	1	2%
L10	28	65%
L50	8	19%
L100	6	14%
	Test	100%

Table 16 Severities Robot issues

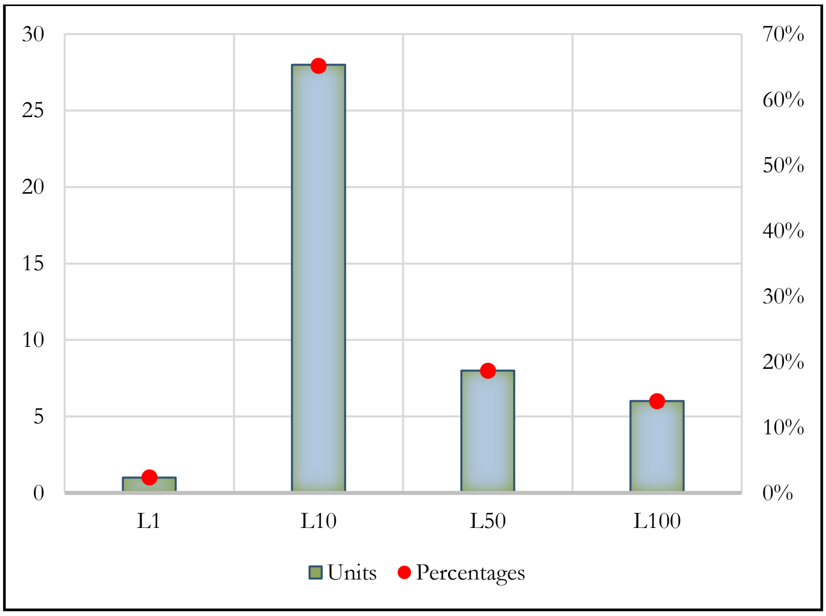


Figure 6-5 Severities Robot issues

A clarification: the L1 severity anomalies, although reported, are not converted into IMAN due to the very low priority and frequency.

II. What is most interesting are certainly the areas of impact of the anomalies, which are not affected at a percentage level by the project status progress: in this aspect, what can be deduced from the percentage data is that the anomalies detected are mainly related to the areas in which the system interacts with devices and networks external to the car. This is also quite predictable given that the information flows that can generate conflicts, overloads or errors that go outside the software specifications of the system can only come from the external environment, while the internal flows are more simply manageable by the system and already validated in the product development phase.

Impact area on test object		
Home	1	2%
Status Bar & App Drawer	7	16%
Media	2	5%
Comfort	4	9%
Navigation	8	19%
Telephone	5	12%
Projection mode	11	26%
Vehicle	1	2%
VR	4	9%

Table 17 Impact area Robot issues

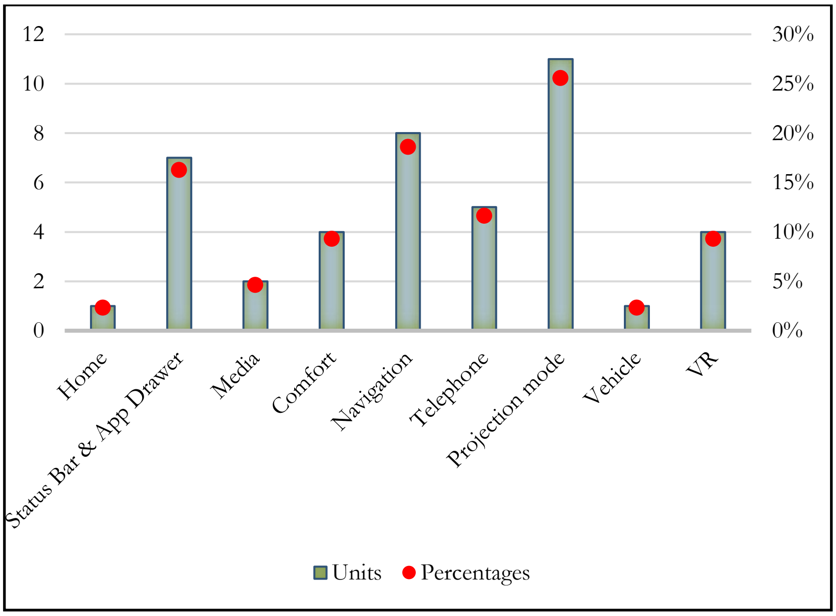


Figure 6-6 Impact area Robot issues

III. The last data, very interesting and surprising, concerns the type of anomaly: despite the evaluation made above on the status project, it appears that the highest percentage, moreover in a considerable way, is of the "new" type, while, more reasonably, the "repeated cases", which are issues with the same specific characteristics and boundary conditions as the new, clearly outweigh the "edited" ones (occurrence of the same anomaly with slightly different boundary conditions).

Type		
New	27	63%
Edited	5	12%
Repeated case	11	26%

Table 18 Types Robot issues

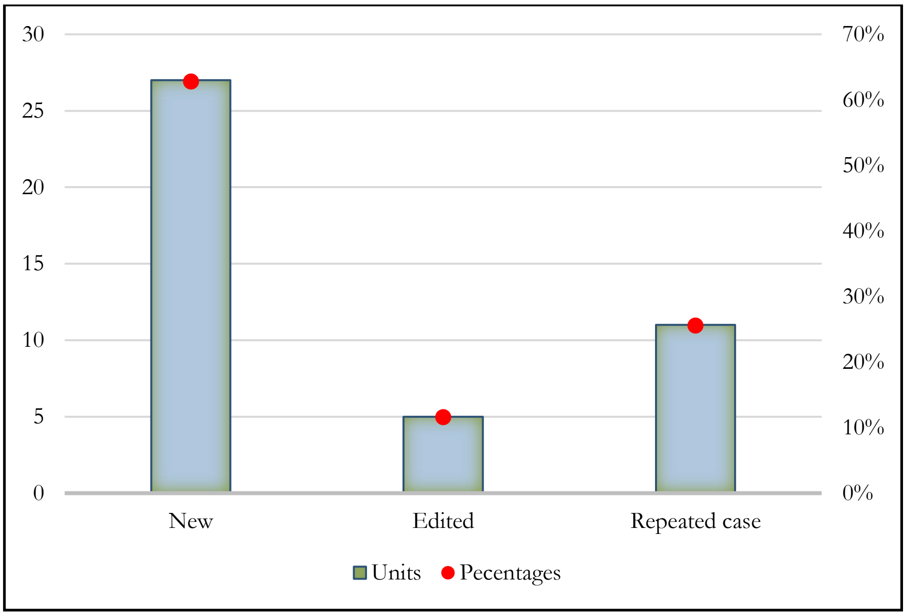


Figure 6-7 Types Robot issues

Here too, however, a clarification must be made: the request of the Reliability Managers is to indicate as a "new" type the anomalies which, although they are very similar to some already reported and open on IMAN, have different boundary conditions, of particular attention is obviously the software version of the system.

6.3.2. QUANTITATIVE ANALYSIS

From a quantitative point of view, in the first analysis the number of anomalies was collected during a predetermined period of time, as anticipated above, which coincided with the release of the software version R16.27 R1 High on the vehicle supplied for the platform by 04/01/2021 until 09/02/2021 that is the date of conclusion of the internship in the company: in this way it was possible to extrapolate not only the performances in absolute terms but above all in temporal frequency, thus generating a KPI more indicative of the real potential of the platform.

At the same time another collection was conducted to carry out a second analysis, this time for comparison: the collection included the anomalies found by a specialist of the institution on the same software version in the same period of time (but not, for obvious reasons, on the same car); the data, provided by Infotainment Quality, were then adapted to make a comparison as precise as possible on the performance of the new platform with those resulting from the application of the traditional testing methodology.

WEEK	ID	SEVERITY	CYCLE	TYPE	AREA
1	1	100	s	n	tbm
	2	50	s	n	info
	3	100	s	n	info
	4	100	s	n	info
	5	10	d	e	info
	6	10	s	n	tbm
	7	50	s	n	info
	8	50	s	n	ipc
	9	100	s	e	info
2	10	100	d	n	info
	11	50	s	n	info
	12	100	s	e	info
	13	10	d	e	info
3	14	10	s	n	info
	15	100	s	n	tbm
4	16	50	s	e	info
5	17	50	s	e	info
6	null	null	null	null	null

Table 19 Specialist issues collection table

As concerning the anomalies detected by the robot the number of total anomalies in the specific period was 43. To make this figure more indicative of real performance, as already mentioned, it was decided to normalize this absolute figure over a time interval, thus establishing a detection frequency indicator.

First, the days of actual use were counted, then the daily hours were counted, taking into account a corrective coefficient that considered the operational and physiological losses of the operator and finally the amount of total hours of use in the period was calculated circumscribed: the data that emerged are visible in the table below.

Robot	
Amount of non-operational robot days	22
Amount of operational robot days	14
Amount of hours of robot use for testing per day [h/d]	6,5
Total theoretical hours of use [h]	91
Corrective coefficient / operational losses	0,7
Total hours of use [h]	63,7
Amount of anomalies detected in the specified period on sw R16	43
Normalized anomalies on operating hours [unit / h]	0,68
Normalized anomalies on operating days [unit / days]	4,39

Table 20 Detection frequency

The two frequency indicators are respectively on the hour and on the working day (considering the working day as the amount of hours of robot use for testing).

The same calculation procedure was also carried out for the issues detected by the specialist and in addition, to perform a qualitative comparison, also trend charts were created based on the same characteristics of the qualitative analysis carried out on the Robot, with the addition of the "cycle" feature.

By connecting to the quantitative analysis, it can be deduced that the type of test conducted is not a real customer use as the robot stresses the system to such an intensive level that it cannot be replicated absolutely by an average user of the product; in fact, the number of anomalies detected through the platform is placed on a further level of exploitation of the system and, although it is based on a model of use similar in form, it is not comparable in terms of stress applied. This is certainly a point in favor, partly anticipated in the paragraph on functional benefits, which allows the embedded system to be validated more effectively than, for example, the method for acquiring anomalies by the drivers.

6.3.3. ROBOT – SPECIALIST COMPARISON

To better contextualize the analysis, as already mentioned, it was decided to make a comparison between the data obtained from the use of the platform and those resulting from the testing of a specialist; the survey period and the system software are clearly the same with the aim of homologating the statistical sample as much as possible.

The main difference in sample sizing is found in the total amount of testing hours as the specialist in his weekly activity only partially dedicates his time to the same platform specification: also for this reason the hourly normalization is essential. In fact, in our sample, the weekly use by the specialist was quantified in 16 hours, divided equally over 5 days for simplicity.

In the table below you can read the results:

Robot		Specialist	
Amount of non-operational robot days	22	Amount of non-operational specialist days	18
Amount of operational robot days	14	Amount of operational specialist days	18
Amount of hours of robot use for testing per day [h/d]	6,5	Amount of hours for testing by specialist per day [h/d]	3,2
Total theoretical hours of use [h]	91	Total theoretical hours of use [h]	57,6
Corrective coefficient / operational losses	0,7	Corrective coefficient / operational losses	0,6
Total hours of use [h]	63,7	Total hours of testing [h]	34,56
Amount of anomalies detected in the specified period on sw R16	43	Amount of anomalies detected in the specified period on sw R16	17
Normalized anomalies on operating hours [unit / h]	0,68	Normalized anomalies on operating hours [unit / h]	0,49
Normalized anomalies on operating days [unit / days]	4,39	Normalized anomalies on operating days [unit / days]	1,57

Table 21 Detection frequency comparison

Limiting itself to reading the detecting frequencies, the comparison leans in favor of the robot and this fully respects the premises and forecasts; however, it is necessary to specify, as already described in detail, that the specialist's activity is very different and decidedly more complex than issue detecting alone.

In addition, other surrounding variables come into play with respect to the use of the platform: first of all the testing cycles are also carried out in dynamic mode, in addition the software testing areas do not include only the HU (Head Unit) of the Infotainment system but also the 'IPC (Instrument Panel Cluster), which is actually another interface of the same system, and the TBM (Telematic Box Module).

In the next pages there are the data of the issues identified by the specialist:

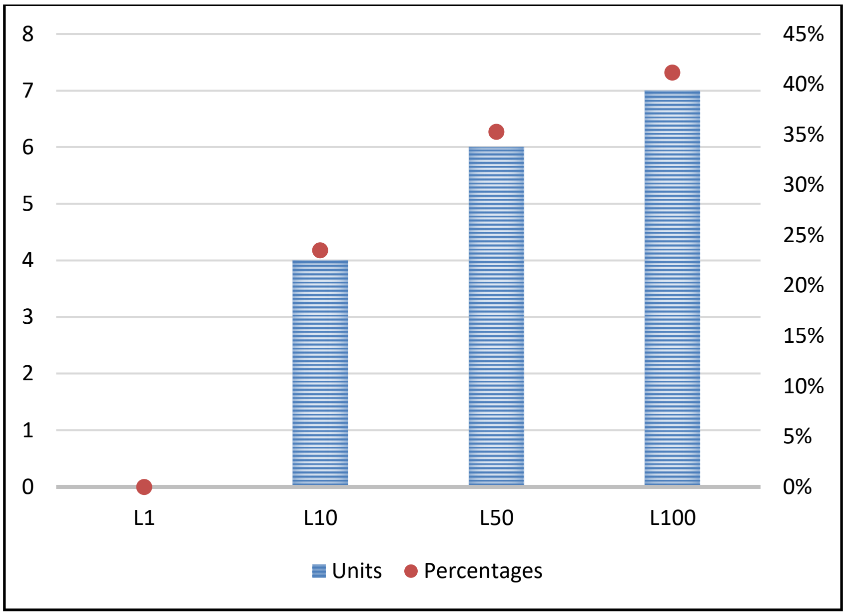


Figure 6-8 Severities Specialist issues

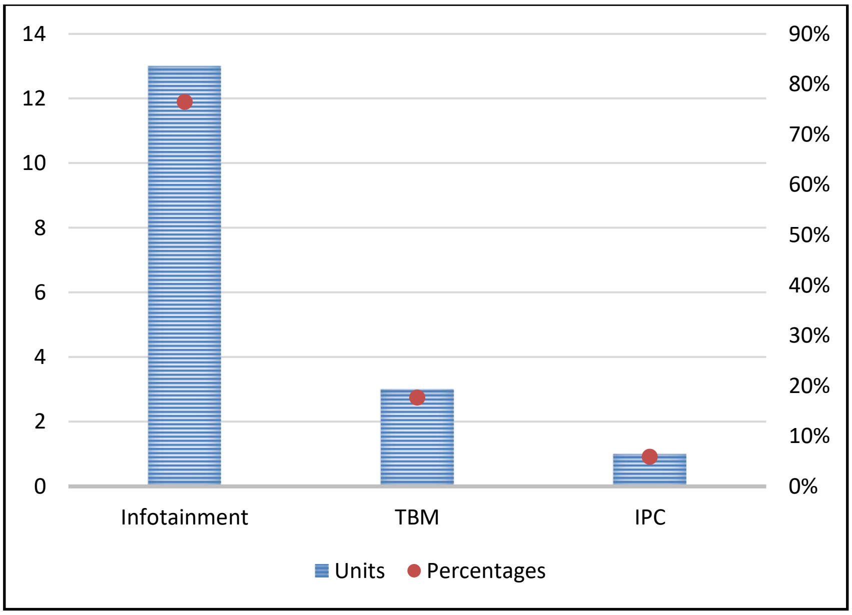


Figure 6-9 Main impact area Specialist issues

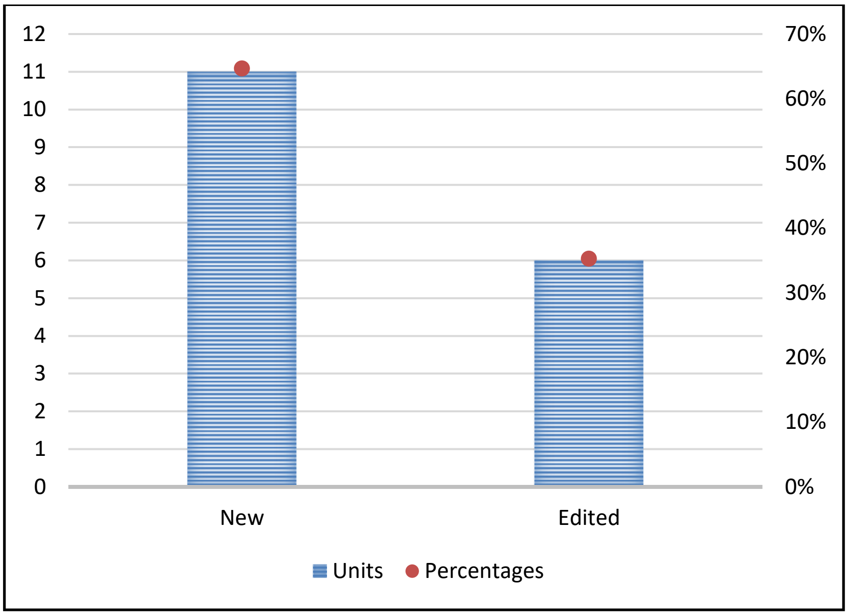


Figure 6-10 Types Specialist issues

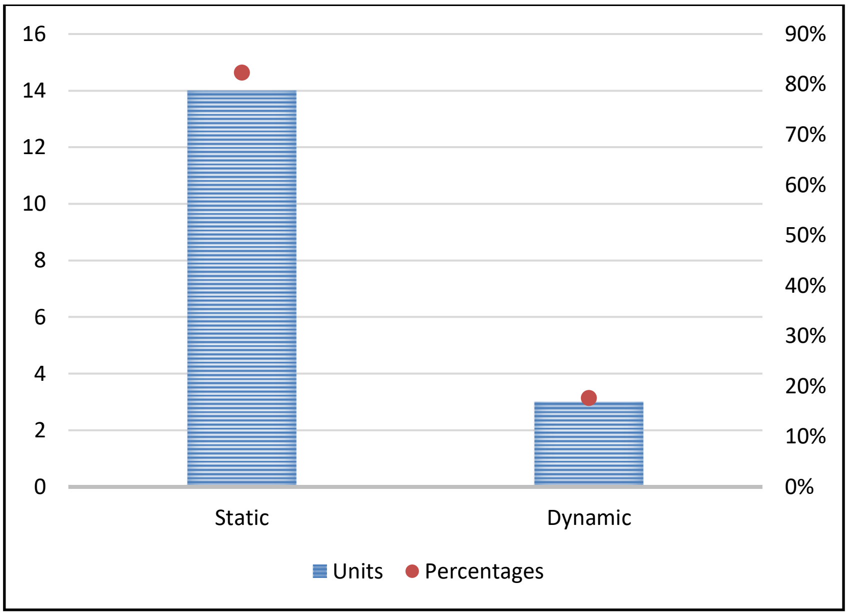


Figure 6-11 Cycle Specialist issues

The different type of activity finds its main confirmation in the comparison of the severity of the issues detected: in fact, compared to the robot, the proportions are inverted with a clear superiority of the high range severity, underlining how much the research work of a specialist is essential and currently more versatile.

	Week 2021	Robot	Specialist
January 2021	1	7	9
	2	12	4
	3	14	2
	4	6	1
February 2021	5	3	1
	6	1	0
	TOT normalized per week	8,0	3,1
	TOT	43	17

Table 22 Calendar: issues recap

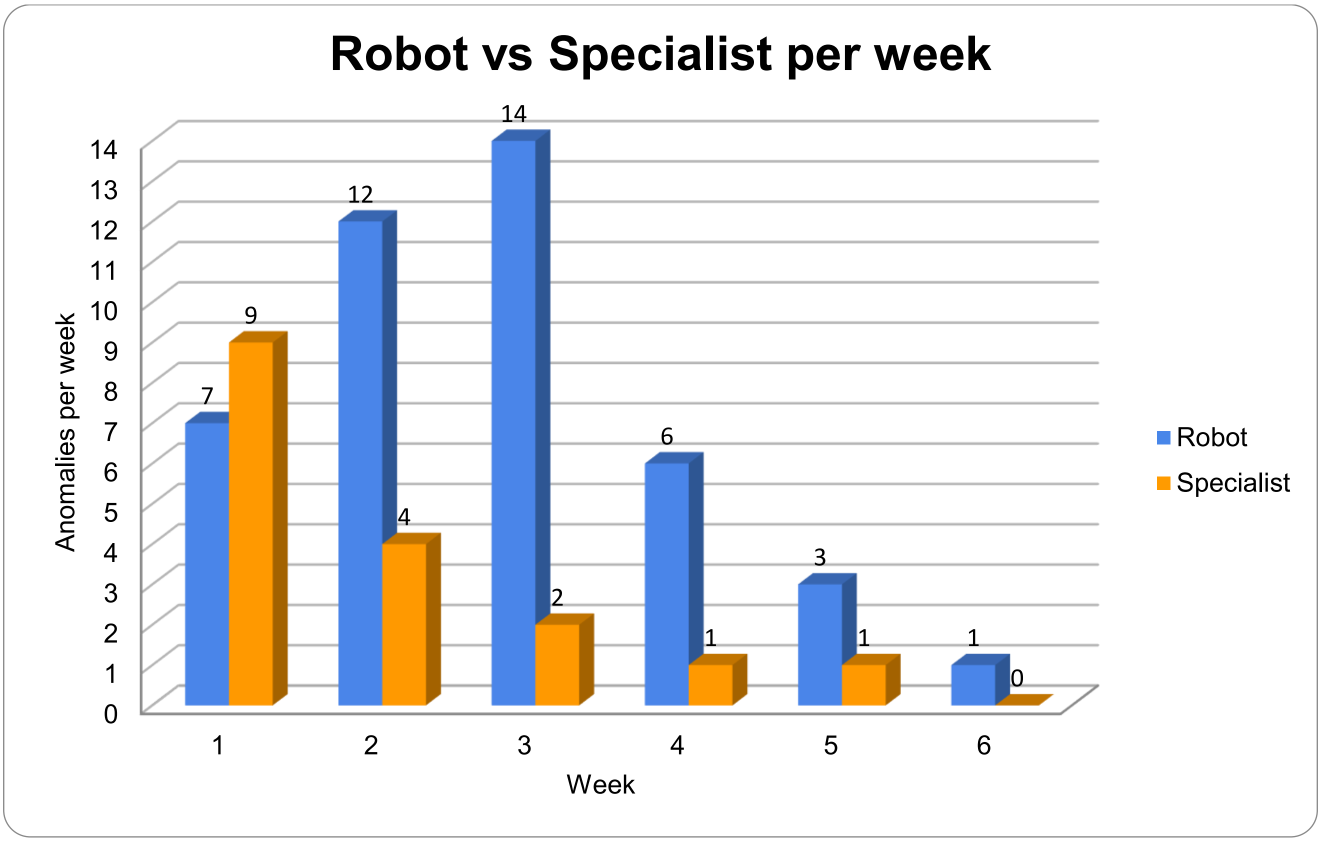


Figure 6-12 Calendar: issues recap

6.4. FUTURE SCENARIO

The possible future implications of the application and the margins for improvement are certainly large since this is one of the first, if not the first ever, robotic automations in the testing phase.

What emerges from the reading of the data and which is applicable in the immediate future is that the main specific applications of the platform in the testing context are essentially of two types: stressing testing and reappearing testing, clearly in static conditions, which in any case include a large slice of possible occurrences.

Another aspect that should not be underestimated for immediate developments is the need to have more than one contingent resource and, possibly, a higher number of licenses for the use of Dexter software for just in time monitoring of the conduct of the tests.

Reconnecting to this last consideration, the possibility of making the platform connected to a remote management system would be a very important innovation and absolutely in line with the needs of digital renewal: not only in terms of security but also in functional ones there would be countless advantages in conducting automatic tests outside the central shift (from 6pm to 9am the following day and on weekends) with the possibility of proactive and immediate control in response.

Another point to verify, but on which in reality the concerns are minimal as the sample used was in itself convincing, is the use of the car on other cars and the procedure by which these are replaced independently, without the supervision of Comau suppliers: it is certainly a procedure that requires experience to be made fast, effective and without potentially dangerous impacts; moreover, the change of the car involves the modification of a whole series of spatial parameters that must be correctly handled by the operator and then considered in the programming phase of the test suit, but, as anticipated, the fact of having tried in the project validation phase on a very compact car like the 500 BEV, it makes this consideration secondary to others and ensures that the compatibility problem of the platform with the company's wide range of cars is not even raised.

By focusing, on the other hand, on the possible improvements to be proposed to the supplier and the company in a broader strategic plan, motions can be raised and new possible scenarios can be generated:

- Is a single platform an adequate number or do you need more units? The answer to this question is not trivial, there is probably no absolute answer; having other similar platforms, which are installed in Mirafiori or in other factories with active Quality bodies, does not necessarily imply an improvement in the testing process and the risk of excessive redundancy and an increase in costs in the short and medium term is serious, on the other hand, the possibility that other automotive companies will buy the product from Comau, this time in a plug & play version, is certainly plausible. The strategic advantage of FCA is to have a product already consolidated in the process and integrated into the company's Quality standards that can be exploited with a view to more frequent vehicle launches and Infotainment systems according to market needs, while purchasing new unity can be asserted as low priority in the short and medium term.

6.4 FUTURE SCENARIO

- To make the most of part of the machine's functions such as the vision system and the AI sound recognition engine, the environment in which it is to be installed should have certain characteristics, such as soundproofing and light insulation (the light intensity must remain stable over time); on the other hand, during the design phase of the product, FCA's request was for the maximum simplification of the accessibility of vehicles and people. This opens up two possible scenarios: maintaining the designed configuration, i.e. the current one, or structuring the testing environment so that the above functions can be exploited; also in this case there is no absolutely correct answer and it depends on the use that will be made of the platform in the future, what can certainly improve is the technological potential of the AI systems that could overcome these problems.
- As for the Robot, a decisive advantage for a more compact and versatile product would be the replacement of the Big Robot with an alternative solution that is less bulky and lighter and more agile but equally rigid and stable; Furthermore, this alternative should not affect the structure of the vehicle tested and not alter its interior composition. Clearly, several options had already been evaluated in the design phase but none of these solved all the problems and the "double robot" solution had been chosen, may Comau R&D find a more efficient technological solution in the future.
- Finally, on the software front, some small updates would be really effective: first of all Dexter's greater flexibility in managing the test sequences, implementing the possibility of modifying them just in time within the TAB Test Player, thus generating an additional test variable. and an optimized management even for long sequences; secondly, the Alcon algorithm of the vision system could in the future analyze not only small portions of the video screen but the whole screen thus making it easier to implement the control checks during the drafting of the individual test cases.

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The images of paragraphs 3.2.1. and 3.2.2. are extracted from the Dexter software (graphic interface) of COMAU S.p.A.