

A Web and Cloud-Based Measurement System Analysis Tool for the Automotive Industry

C. A. Barros, Ana P. Barroso

Abstract—Any industrial company needs to determine the amount of variation that exists within its measurement process and guarantee the reliability of their data, studying the performance of their measurement system, in terms of linearity, bias, repeatability and reproducibility and stability. This issue is critical for automotive industry suppliers, who are required to be certified by the 16949:2016 standard (replaces the ISO/TS 16949) of International Automotive Task Force, defining the requirements of a quality management system for companies in the automotive industry. Measurement System Analysis (MSA) is one of the mandatory tools. Frequently, the measurement system in companies is not connected to the equipment and do not incorporate the methods proposed by the Automotive Industry Action Group (AIAG). To address these constraints, an R&D project is in progress, whose objective is to develop a web and cloud-based MSA tool. This MSA tool incorporates Industry 4.0 concepts, such as, Internet of Things (IoT) protocols to assure the connection with the measuring equipment, cloud computing, artificial intelligence, statistical tools, and advanced mathematical algorithms. This paper presents the preliminary findings of the project. The web and cloud-based MSA tool is innovative because it implements all statistical tests proposed in the MSA-4 reference manual from AIAG as well as other emerging methods and techniques. As it is integrated with the measuring devices, it reduces the manual input of data and therefore the errors. The tool ensures traceability of all performed tests and can be used in quality laboratories and in the production lines. Besides, it monitors MSAs over time, allowing both the analysis of deviations from the variation of the measurements performed and the management of measurement equipment and calibrations. To develop the MSA tool a ten-step approach was implemented. Firstly, it was performed a benchmarking analysis of the current competitors and commercial solutions linked to MSA, concerning Industry 4.0 paradigm. Next, an analysis of the size of the target market for the MSA tool was done. Afterwards, data flow and traceability requirements were analysed in order to implement an IoT data network that interconnects with the equipment, preferably via wireless. The MSA web solution was designed under UI/UX principles and an API in python language was developed to perform the algorithms and the statistical analysis. Continuous validation of the tool by companies is being performed to assure real time management of the 'big data'. The main results of this R&D project are: MSA Tool, web and cloud-based; Python API; New Algorithms to the market; and Style Guide of UI/UX of the tool. The MSA tool proposed adds value to the state of the art as it ensures an effective response to the new challenges of measurement systems, which are increasingly critical in production processes. Although the automotive industry has triggered the development of this innovative MSA tool, other industries would also benefit from it. Currently, companies from molds and plastics, chemical and food industry are already validating it.

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I. INTRODUCTION

THE close contact with the industry for more than a decade, especially in the automotive industry, has identified the need to develop a solution to run and manage the MSA in a web and cloud-based approach, a philosophy different from that followed by the existing solutions in the marketplace. So, the web-based and cloud-based MSA tool must meet the following requirements: i) it does not require an Information Technology (IT) infrastructure; ii) that is 100% configurable by the user; and iii) that allows the integration of new features any time and its immediate dissemination by users.

Currently, the paradigm of web-cloud systems is still not common in enterprise applications due to lack of confidence in the cloud-computing model [1], but it will certainly be unavoidable. In this type of model, it is no longer necessary to have local servers, allowing to gain some advantages. It reduces costs, both fixed and variable, since the data are stored in a cloud, public or private, whose costs structure is defined by a pay-as-you-go price model. On the other hand, it increases speed, security, flexibility and the ensuring system availability 24/7, anywhere [1].

To take full advantage of the potential of cloud computing it was necessary to redesign the software development strategy. Fig. 1 shows the development approach followed by this responsive solution, which is called ACCEPT MSA, designed according to UI/UX principles. The “backbone” of the solution is based on an API Application that feeds the MySQL database (a relational database management system based on Structured Query Language) where the data and business logic are implemented. There is also an API Statistics, in Python, that integrates the algorithms used in the MSA and their statistical calculations. In order to ensure connection to different devices, an API Device has been developed in node.js, which is part of the backend along with the API Statistics and the API Application, as well as the Link application. The frontend is developed in Vue.js, a Javascript framework, and Laravel, a PHP framework (a script language and interpreter, also called Hypertext Preprocessor). This solution with this new approach is intended to change the *modus operandi* (Fig. 2) that is usually found at the quality and process control laboratory. Typically, the analyst team manages the equipment, performs measurements and classifies/categorizes attributes. The analysts record data manually on paper and then in excel files. This process presents several non-added value activities and is

characterized by a high probability of error. Therefore, it must be changed. Fig. 2 illustrates both the current situation (as is) and the future situation (as to be) that results from the vision of the present R&D project to develop the MSA tool.

To ensure quality and compliance of data, the automotive industry developed standards such as the IATF 16949: 2016 (formerly ISO/TS 16949) [2], the manual “MSA-4” [3], from AIAG, and the "Measurement System Capability - Reference manual" [4].

According to the ISO Survey 2016 [5], in 2016 more than 67 thousand (67,358) companies worldwide were certified by ISO/TS 16949, with the following distribution: around 40 thousand (39,986) in Asia and the Pacific (59,4%), approximately 13 thousand (12,786) in Europe (19,0%) and the rest (6,389) in North America (9,5%). From 2010 to 2016 there was, on average, an increase of 7% per year. This growth trend allows to perceive the market potential that exists for this type of solution.

In October 2016, a multidisciplinary team was set up to develop an R&D project, called ACCEPT MSA, funded under the Portugal 2020 program.

The multidisciplinary team is made up of designers, researchers and programmers from a company (SINMETRO) and a university (Universidade NOVA de Lisboa). With the main purpose of contributing with their comments (feedback) on the design and capabilities of ACCEPT MSA, three tester companies from different industries, Aferymed, Novares and Prio of legal metrology, automobile and fuels, respectively, are also included in the project (Fig. 3). This multidisciplinary team is working together to develop the web and cloud-based

MSA tool to meet current and future market needs. This project is aligned with the vision of "digital transformation" of the 4th Industrial Revolution that combines concepts such as: industrial internet, "smart factory" and, mainly, IoT.

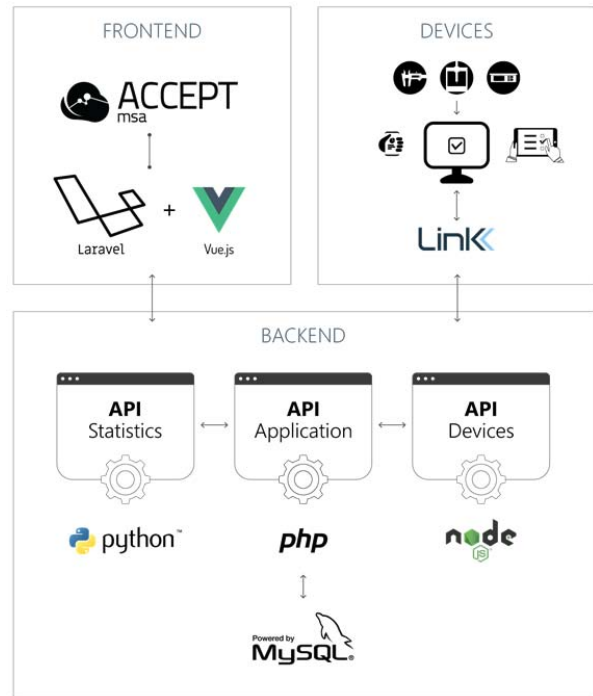


Fig. 1 Web and cloud infrastructure of ACCEPT MSA

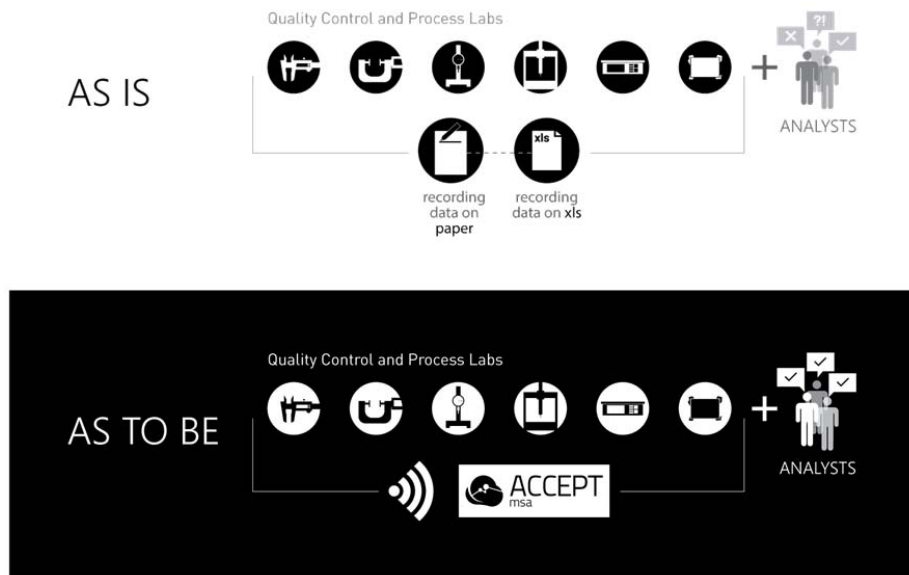


Fig. 2 Current situation and R&D project vision

II. METHODOLOGY

To ensure innovation and a high scientific level, the approach in the development of the project can be summarized in the following six steps:

1. Benchmarking of current competitors and respective

commercial solutions linked to the Industry 4.0 paradigm, which present real-time data analysis and are interconnected with devices, equipment and software on the shop floor. Analysis of the main advantages (concerning the price, embedded technologies,

functionalities, reports that can be extracted, etc.), deficiencies/areas not covered, languages, type of

application (web, desktop, etc.), among other aspects.

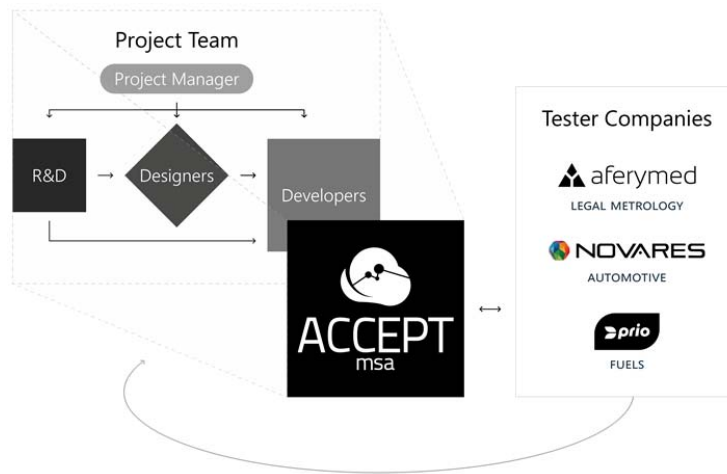


Fig. 3 Project team and tester companies of ACCEPT MSA

2. Analysis of the size of the target market for the MSA tool, i.e. companies that have bet on Industry 4.0 initiatives, particularly companies that do not have a well-defined modernization strategy and that have focused on ad-hoc implementations in the markets of Portugal, Spain, Germany and England.
 3. Definition of the objectives and goals to be achieved in the present R&D project, through the collection of information and knowledge in scientific publications, books and papers, to characterize the state of the art.
 4. Assessment of the technical and technological challenges to be achieved with the R&D project and assessment of the project team's ability to respond to these challenges, as well as the identification of areas that may require subcontracting.
 5. Detailed definition of the activities, tasks, milestones and deliverables of the project and the respective scheduling, allocation of resources and determination of the project budget.
 6. Execution of the project, as planned, with a continuous evaluation of the achievement of the objectives, within the expected time and cost, and with the safeguard of the management of the generated intellectual property.
- The methodology used to develop the MSA tool comprises the following ten phases:
1. Definition of the IT strategy and infrastructure.
 2. Understanding of data flow and traceability requirements.
 3. Implementation of an IoT data network and an API in node, that interconnects with the equipment, preferably via wireless, to databases that are associated with statistical treatment tools and algorithms that ensure its traceability.
 4. Definition of the key performance indicators to measure the performance of the MSA process.
 5. Designing the MSA solution beyond UI/UX principles.
 6. Continuous validation of the design with tester companies.
 7. MSA tool development, web-based and cloud-based.
 8. Development of an API, in Python language, to implement the MSA algorithms and perform the statistical analysis.
 9. Testing of the MSA tool using simulation and in real environment.
 10. Real time management of the "big data", transforming data into knowledge.
- The main challenge launched by this project was to develop an MSA tool with a high degree of research, development and integration to the market for companies, mainly certified by IATF 16949:2016 [2], which aim to completely change its modus operandi, since they know that it is inefficient and not optimized. In order to develop this tool, six core activities have been defined to generate a continuous flow of deliverables and milestones. Fig. 4 shows in a succinct way the Gantt chart of the work plan.

III. STATE OF THE ART OF MSA TOOLS

The proposed approach to MSAs, as well as the algorithms to be used, is presented at the scientific references within the scope of quality control such as [9]-[12].

The manuals that the automotive industry takes as reference and which are accepted and followed by all companies in this type of industry are the AIAG MSA Handbook [3], known by AIAG MSA-4 Handbook, which is already in the fourth edition, and the Measurement System Capability-Reference Manual [4]. The two manuals define several MSA studies, especially the most relevant, which depend on the type of data: i) continuous (e.g. weight, temperature, pressure, dimensions, etc.) and ii) attributes (e.g. classification of defects/organoleptic characteristics, etc.).

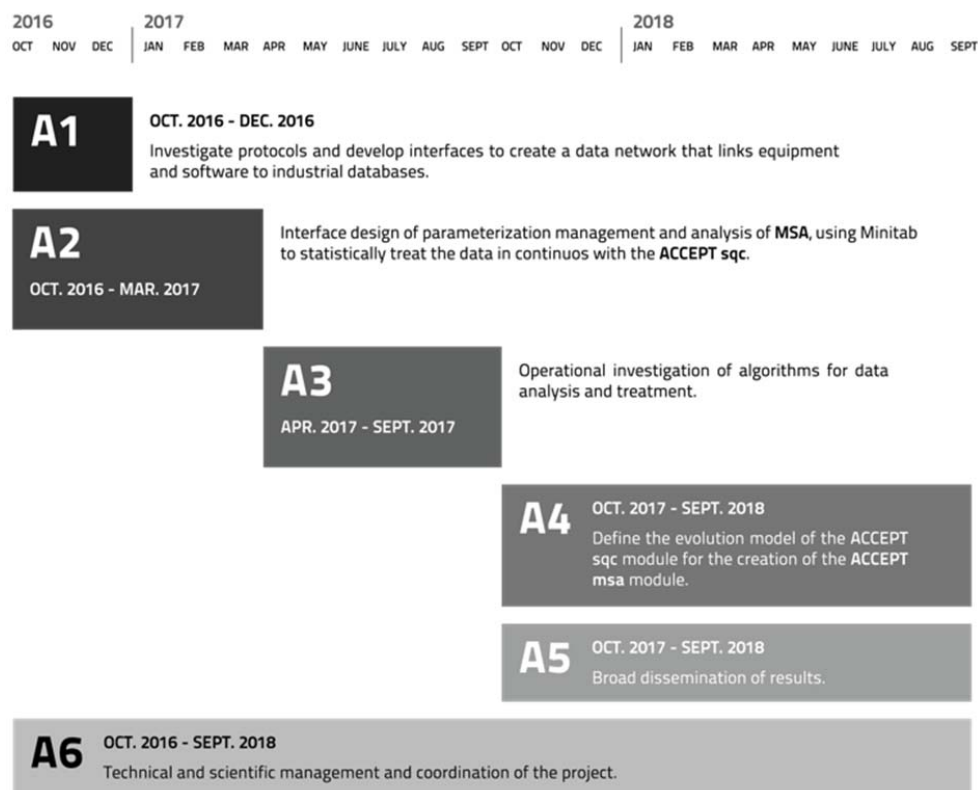


Fig. 4 Project Gantt Chart

Although the AIAG MSA-4 Handbook [3] is quite complete, there are situations where it cannot be applied literally. Moreover, on page 210 of this manual, it is stated that the methods described are only valid if the test conditions reflect the conditions assumed for the formulation thereof. When the test conditions do not reflect the assumed conditions the quality engineer must make certain corrections, either through correction coefficients or through alternative methods.

There is also an increasing number of publications that question the methods and techniques used by AIAG MSA-4 Handbook [3]. Examples that should be highlighted are i) the two publications [6] and [7], which question the use of the standard deviation instead of the variance in the calculations performed, as this may lead to unreliable results, and ii) the answer of AIAG [8].

More and more industries are working with measurement solutions in the order of hundredths of a millimeter, reaching a thousandth in certain components, so that any calculation error derived from approximations can have serious consequences on production. It is therefore important not only to comply with the manuals [3] and [4], since they are industry standards, but also to investigate and test new methods and calculation techniques that advance the state of the art. For this reason, the development of new computational algorithms and the improvement of existing algorithms were the main lines of the research considered in this project to assist quality technicians in meeting MSA requirements.

From benchmarking, there is only one software that has MSA studies, the IQMS that is a manufacturing Enterprise

Resource Planning (ERP) software, which enables direct integration with measuring devices and ERP systems. This software, however, is quite limited in the type of statistical tests used to perform the MSA studies, providing only control charts of the average and amplitude type, which does not allow to fully investigate the causes of variation of a measurement system.

Systems like MINITAB, QISOFT, INFINITYQS, SYMPHONYTECH and ZONTEC-SPC are also used as a benchmark. MINITAB software implements the statistical tests in the AIAG manual, however it is a statistical software for offline data analysis, which i) does not allow to be integrated with measurement equipment, ii) is dependent on the manual data entry by an operator, and iii) does not allow automatic analysis of the history of MSA studies for a given measuring system.

IV. CONCLUSION

The web and cloud-based MSA tool developed in the R&D project for the validation of measuring systems is presented in Fig. 5 and responds to the following technical and technological challenges:

1. Be a web and cloud-based solution, as described in Fig. 1.
2. Be fully configurable by the user, easy to use and responsive.
3. Integrate the MSA methods proposed by the reference manuals [3], [4], as well as methods developed by the team with the three tester companies for internal calibrations and verifications, such as the evaluation of

the equipment bias degradation over the range, and over time, using linear regression models, repeatability analysis of automatic measurement systems, repeatability and reproducibility studies for attribute and the definition of the classification system and proper statistical analysis.

4. Be interconnected with measuring systems, avoiding manual data entry.
5. Ensure traceability of all statistical tests.
6. Include statistical tools to monitoring MSA over time, allowing the analysis of deviations from previous studies.
7. Allow management of the measuring equipment with a powerful tool of searching and indexation.

The main results of this R&D project were:

- ACCEPT MSA web and cloud-based solution
- API Application
- API Statistics
- API Devices
- New Algorithms to the market
- Style Guide of UI/UX of the solution.

This MSA tool can be used by any industrial company that needs to i) guarantee the reliability of their data, and ii) study the performance of its measurement system in terms of linearity, bias, repeatability and reproducibility, stability, among others.

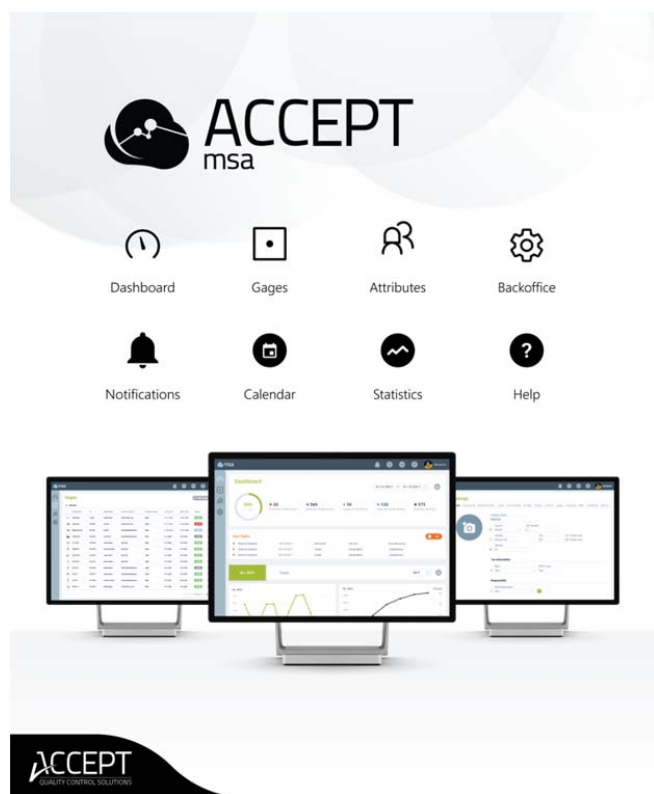


Fig. 5 The web and cloud-based MSA tool

ACKNOWLEDGMENT

For this project was crucial the participation of the three tester companies, Novares (Automotive), Prio (Biofuels) and AFERYMED (legal metrology), which supported the team

with system specifications, examples and real data to perform the tests. Without this contribution it would have been very difficult to get this solution so quickly and respond to industry needs.

REFERENCES

- [1] H. T. Dinh, C. Lee, D. Niyato, and P. Wang, "A survey of mobile cloud computing: architecture, applications, and approaches," *Wireless*, vol. 13, no. 18, pp. 1587 – 1611, October 2013.
- [2] I.A.T.F. - International Automotive Task Force, *IATF 16949: Quality management system requirements for automotive production and relevant service parts organizations*. 1st Ed, SMMT Publications, 2016.
- [3] A.I.A.G - Chrysler Corp., Ford Motor Co., General Motors Corp., *Measurement Systems Analysis (MSA), Reference Manual*. 4th ed., Michigan (USA), 2010.
- [4] Audi AG, BMW AG, Robert Bosch GmbH, DaimlerChrysler AG, Fiat Auto S.p.A., Ford-Werke AG, Adam Opel AG, Q-DAS® GmbH, T.Q.M. Itaca s.r.l., Volkswagen AG, "Measurement System Capability - Reference Manual", Version 2.1 D/E, September 2002.
- [5] International Organization for Standardization ISO, "The ISO Survey of Management System Standard Certifications 2016, Excel File: "07. ISO/TS 16949 - country per country - 2004 to 2016," November 2017.
- [6] D. S. Ermer, "Improved Gage R&R Measurement Studies," *Quality Progress*, vol. 39, no. 3, pp. 77-79, March 2006.
- [7] D. S. Ermer, "Appraiser Variation in Gage R&R Measurement," *Quality Progress*, vol. 39, no. 5, pp. 75-78, May 2006.
- [8] L. A. Brown, "AIAG Team Member Respond to Columns," *Quality Progress*, vol. 39, no. 7, pp. 8-10, July 2006.
- [9] B. C. Gupta, and H. F. Walker, *Applied Statistics for the Six Sigma Green Belt*. Milwaukee: Quality Press, 2005.
- [10] A. M. Joglekar, *Statistical Methods for Six Sigma in R&D and Manufacturing*. USA: John Wiley & Sons, 2003.
- [11] D. C. Montgomery, *Introduction to Statistical Quality Control*. Hoboken NJ: John Wiley & Sons, 2012.
- [12] T. Pyzdek, and P. A. Keller, *The Six Sigma Handbook*. New York: McGraw Hill, 2010.