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Real-Time Nonconformity Management in SMEs Within the Internet of Things and Industry 4.0 Concepts

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Abstract

This paper proposes a software answer for nonconformity detection and preventive and corrective moves definition. The solution objectives to increase the usage of part gadgets in compliance with Industry 4.0 and Quality 4.0 paradigms. The software program answer layout is based on the JavaScript programming language and its capability to be applied throughout all software program solution levels thru interconnected frameworks (MongoDB, Express.Js, Angular, and Node.Js) in a MEAN stack architecture. The advanced answer has been carried out in 3 small and medium organisations. Initial consequences show numerous benefits, together with elevated nonconformity detection and reporting. All nonconformities were linked to precise sections of the ISO 9001:2015 requirements, enabling satisfactory managers and enterprise managers to benefit perception into the assets of the problems and establish a foundation for defining suitable managerial moves. The paper's important contribution is the presentation of this software solution, which is intended to offer a lower priced approach for the identity and large reporting of nonconformities, incorporated with different software program modules. This approach aligns with the ideas of Industry 4.0 and Quality 4.0, leveraging edge gadgets and facts-driven insights to enhance exceptional management methods within businesses.

Keywords: Information technology, Inspection, Industrial engineering

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1. INTRODUCTION

This paper primarily intends to demonstrate that technologies from the Industry 4.0 (I4.0) toolset could be implemented in Quality Management (QM) and Nonconformity Management (NCM), making an essential step towards I4.0 and Quality 4.0 (Q4.0) convergence (Zhou, Liu, & Zhou, 2015). To achieve this goal, authors have developed and implemented an innovative software solution with several advantages affordable for Small and Medium Enterprises (SMEs). Developed software application for mobile devices will enable all employees to report and manage NCs using the steps and directives from ISO 9001:2015 (detection, reporting, decision-making, and the definition of preventive and corrective actions). The main contribution reflects in the presented software solution for affordable identification and massive workload Nonconformity (NC) reporting, integrated with other software modules for quality analysis and prediction. In this way, it is possible to obtain horizontal scalability and richness of the proposed software solution for smart enterprises focused on World Class Manufacturing and Lean manufacturing. The presented solution usage contributes to all participants involved in the organisation of production and production itself, through (1) involvement of all employees; (2) digitalisation and improvement of existing nonconformity reporting systems; (3) improvement of nonconformity perception; (4) improved awareness and evaluation of employer's contribution to nonconformity management; (5) making the technology easy to use inexpensive and suitable for a wider industry audience.

In the following sections of the paper, the authors have presented the concept of NCM in I4.0 (Section 2), with the proposed general software components and their relationships design (Section 2.1) and process flowchart (Section 2.2) included. Additionally, mobile devices, cloud and Q4.0 application trends, JavaScript, and Typescript based solutions have been considered. Lastly, the authors have presented a specific case of developed software infrastructure, with the possible benefits of the solution (Sections 3 and 4).

2. THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 Industry 4.0 and Quality 4.0 concepts

I4.0 ought to improve the information flow throughout the entire organisation, enabling better control and operations to be adapted in real-time (Moeuf, Pellerin, Lamouri, Tamayo-Giraldo, & Barbaray, 2018) to respond to stakeholders' expectations while maintaining a competitive advantage.

In the I4.0, the quality concept has been broadened, and it includes personalised service quality and personalised production. Quality goals have evolved along with the phases of revolution in industrialisation. According to the literature sources (Foidl & Felderer, 2015), crucial preconditions for sustainable economic success in modern manufacturing companies focus on QC, QM, and QMS.

The core concept of Q4.0 encompasses eleven axis (components) according to (Jacob, 2017), including: (1) big data with characteristic of volume, variety, velocity, veracity and transparency; (2) analytics framework that provides descriptive, diagnostic, predictive and prescriptive analysis; (3) connectivity that may enable near real-time feedback from linked edge-devices, people and processes; (4) collaboration through digital messages, description of the activity flows (visual), and social (social) media; (5) app development including mobile applications, platforms, virtual reality, augmented reality, web-client, browser and applications for robot (measurement and manipulation) and machines (CNC, DNC, sensors, etc.); (6) horizontal scalability represents the ability to support a growing and large volume of data, users, devices and analytics globally; (7) management systems that monitor autonomous and connected processes; (8) compliance that among other things includes electronic submission of the compliance/NC reports and automation of flows in the compliance area; (9) quality culture representing among functionally strong cooperation, credibility, and shared responsibility; (10) leadership expressed through quality performances, process ownership, and goal scheduling; and (11) competency considering employees training as one of the most crucial fields for business progress. Therefore, through Q4.0, critical new technologies are affordable and accessible to the broader circle of business organisations, with the provided opportunity to solve long-standing quality challenges and adopt new solutions. Following these suggested axes, the primary objective of this paper is a representation of the mobile solution for NCM that is based on a collection of big data, management support, improved communication between employees, and improvement of quality culture as essential toolset elements in the Q4.0 concept.

2.2 Nonconformity management

Due to increasing market competition, organisations have adopted QMS like the ISO 9000: International Standard Series. According to the ISO survey, 878 664 organisations worldwide have certified ISO 9001:2015 (International, 2015). The establishment of tools for prevention of NCs and elimination of their causes represents a mandatory requirement of QMS, and as such, NCM receives sub-process function in the general production process (Závadská & Závadský, 2018). NCM should (according to ISO 9001:2015) be implemented during the realisation of all organisational processes, and the organisation should retain documented information about NCs. As specified by standard requirements, documented information can be formulated as a report with a description of NC, undertaken actions, obtained concessions and identified authority. Additionally, the standard requires documented information as evidence of any corrective action results, supplementing the report, as mentioned earlier. By utilising the report, corrective and preventive actions are taken to eliminate identified NCs.

This paper focuses on NCM, intending to decrease the number of products and processes of NCs and effectively implement proactive and corrective measures adequate for product and process quality improvement. Ideally, NC and waste should be eliminated, whereby Zero-defect production should be achieved. It is necessary to implement QC in real-time, enabling NC detection in an early process stage and reducing production waste. In general, these requirements could be derived from a standard, a specification, a customer or a stakeholder.

Therefore, the detection and reporting of NC could happen during the audit, inspection, documentation review, product testing, customer complaints, stakeholders feedback, and general observation based on experience (Luca, 2015). In addition to the above, NCs can take many forms and types, which may vary depending on the industry type, so that common NCs include: failure to identify issues, failure to define processes, plans, and schedules adequately, process deviations and product defects, deviations from a specification of product characteristic, missed plan, customer and supplier return. Taking into consideration the facts stated, NC data are scattered throughout different organisation systems in heterogeneous formats. Specific ICT solutions with scalable capabilities could be applied to overcome data formating diversity and heterogeneity, creating a real-time informed decision-making environment for NCM by creating homogeneous digital NC reports.

2.3 Initial presumptions and goals for the current research

The initial presumptions, based on which the research was conducted, are that a sufficient information flow is highly emphasised for the continuous operating of the advanced manufacturing processes and that, however, unpredicted situations and quality issues have to be often resolved by utilising imprecise and incomplete information. Therefore, it is crucial to perform frequent comprehensive and reliable quality inspections to conduct and deliver defect-free and high-quality processes and products and be competitive. Although traditional data analytic techniques and tools have been widely and successfully used for quality inspection, new I4.0 techniques may be applied to mine massive data sets gathered through automated industry architecture.

Following the presumptions mentioned above and demands of Q4.0, including NCs reporting, this research's primary intention is to adopt technologies from the I4.0 toolset (such as cloud computing, artificial intelligence, mobile platforms, advanced information technologies) to demonstrate road to possible transition of quality to Q4.0 model. In this research, the authors will be focused on QM and NCM as essential elements of the quality approach. This paper's authors demonstrated that affordable open-based solutions developed on open source technologies could improve the NCM and basic principles of QM. The authors presume that the development of affordable cloud solutions based on the MEAN stack may be used for real-time NCM to improve basic principles of QMS such as engagement of people, improvement, and evidence-based decision-making.

3. ARCHITECTURE AND CHARACTERISTICS OF DEVELOPED SOLUTION

3.1 Incorporated application and introduction of advantages for Q4.0 and NCM

Based on the stated presumptions and intentions, the requirements for an NC reporting software solution are as follows: the solution has to be able to report stand-alone NC and to assign NC to a specific employee to be managed and resolved; to record one or more preventive/corrective actions and to associate them with reported NCs; to allocate responsibilities for the implementation of the preventive/corrective actions; to investigate notifications, with reminders, to determine correlations between process performances and NCs, within specific periods, utilising statistical analysis methods; to use data storage and further subsequent use to form the necessary knowledge in KDD for the future decision-making processes. Accordingly, the software solution contains the following modules: statistical and communication modules, the module for possible product barcode detection, the module for initial NC reporting, the module for pattern recognition, the module for statistical analysis graphical presentation. The solution can be included in the IoT architecture of the MOs and connected with other databases via web services. The collected data related to the definition NC, its management, identification of products or processes in which NC has occurred, and the proposed actions to resolve the NC can be used to form KDD that may be subsequently utilised, alongside RNN, for pattern recognition and proposal of appropriate preventive/corrective actions.

Figure 1 shows the implementation of the proposed solution based on JavaScript MEAN frameworks' application. The expression MEAN stack represents a set of JavaScript-based technologies appropriate for web applications development. MEAN is an abbreviation derived from the first letters of the used technologies, i.e., MongoDB, ExpressJS, Angular and Node.js. MEAN is an open-source stack with the possibility to develop adjustable and scalable applications, and as such, it is the perfect candidate for cloud hosting (IBM cite 2020). The presentation tier is developed through the Angular framework; the application tier is introduced through Express.js and Node.js capabilities, whereby MongoDB was adopted to define the cloud database. Consequently, technology selection can be considered as an essential aspect, as it affects the cost, performance and possible functionalities of the NCM reporting solution and the overall Q4.0.

If multiple companies apply the solution, collected and integrated data could be used for pattern recognition. In this case, they will learn from each other and have patterns for recognition of NCs and the selection of possible management initiatives. The proposed method has clear advantages because it utilises a new approach in application development to fulfil the principles of QMS. This approach with availability and personalisation increases employees' participation and involvement and provides a broader base for NCM and evidence-based decision making.

The presentation tier is deployed through JavaScript/TypeScript open-source Angular framework. Increased use of Angular framework is derived from the fact that it supports Progressive Web Applications' concept. This concept indicates that an introduced application is: instantly loaded, independent from the network slow or unstable connection, responsive, and, among other things, with features, such as Web Bluetooth API, that makes the application to be more native-like. Node.js represents an asynchronous open-source JavaScript run-time environment carried over Google Chrome's JavaScript engine V8 to create scalable applications independent from the browser. Besides the V8 engine, Node.js contains an abstraction layer library to handle asynchronous events. Node.js unifies application development merely around JavaScript programming language. The NC reporting data are sent from the presentation layer to the business layer in a lightweight data-interchangeably JavaScript Object Notation (JSON) format. This format is language-independent, and it has been fitted for data sharing among interconnected clients. As compact and straightforward, JSON is efficiently generated and parsed by machines and easily read by humans. JSON became a fitting solution for cloud NoSQL database within this study based on the mentioned advantages. MongoDB databases belong to the NoSQL databases class, unlike SQL relational databases, where columns are eliminated, and rows are documents used to store information about the data and the data itself. Since the data are stored in a BSON format that presents a binary JSON document, MongoDB proved to be a reasonable solution for JavaScript-centric application development. This module adds an entire tier of features on top of MongoDB that enables the definition and maintenance of data structure and data models and their utilisation to introduce direct interaction from application code to the database.

3.2 Software solution capabilities

The software solution aims to provide real-time reporting in the NC occurrence caused by deviations in organisation or supplier processes. Adequate NC reporting should comprehend critical elements, such as positioning, identification, documentation, and disposition.

The solution can get the data generally from three sources: manual input from employees and data gathered directly with the sensors incorporated in production and IoT. Through these sensors, dedicated software incorporate functionalities of external devices or sensors connected to peripheral I/O. This option demands customising the solution on the companies perimeter, which includes existing sensors in the system.

Within the presented solution, it is possible to utilise the Recurrent Neural Network (RNN) to detect possible patterns for preventive/corrective measures (Lukoševičius & Jaeger, 2009). RNN is a neural network (NN) class that extends the conventional feedforward NN with loops in connections (Mou, Ghamisi, & Zhu, 2017). RNNs differ from feedforward NN since they can process sequential input data through a recurrent hidden state whose activation in each subsequent step depends on the previous step's activation. In this way, the RNN can expose dynamic behaviour.

For the NC and corrective actions pattern recognition, the given sequence is $nc = (nc^1, nc^2, \dots, nc^k)$ representing NC occurrence descriptions so that the RNN framework can calculate the hidden vector sequence as $h = (h^1, h^2, \dots, h^K)$ by iterating the following equation from k= 1 to K:

$$h^k = \varphi(w_{ih}nc^k + W_{hh}h^{k-1} + b_h)$$

Where w_{ih} indicates the input-hidden weight vector, while W_{hh} denotes the context weight matrix of the hidden layer, b_h is the bias vector in the hidden layer, and $\varphi()$ is the hidden layer activation function (possibly sigmoid or tan-sigmoid function). Finally, predicted corrective action q_a could be computed as follows:

$$q_a = W_{oh}h^K + b_o$$

Where W_{oh} indicates the output-hidden weight matrix, and b_o is the bias vector of the output layer. The motivation is to present different NC occurrences and corrective actions as sequential data so that an RNN can be adopted to model pattern recognition.

3.4 CASE STUDY AND INITIAL RESULTS OF IMPLEMENTATION

The developed solution has been used in three SMEs in plastic and rubber parts production intended for the automotive industry. The NCs of plastic and rubber products could be different, hard to determine and report, or significantly different to detect using classical control systems.

By applying the solution, the employee can document and report NC. It is possible to provide measurement or use correlated barcode data to trace previous similar products of NCs, to acquire the knowledge necessary to presume what to do with this type of NC. The software system using the RNN module provides the mentioned decision and action.

The authors monitored the implementation and initial results of represented software in three SMEs. The data were gathered for six months. Keeping in mind that companies have different production programs and amounts of production and different products, it could be concluded that implementing and utilising such a system improves employees' involvement in the process and quality culture. On the other hand, it enables easier detection, reporting and digitalisation of spotted NCs and reduces reporting and taking actions periods.

The authors detected that recognising the patterns using RNN could help take managerial actions in NCM and QM. From the obtained and presented data, it is evident that the number of detected and reported NC and the number of corrective and preventive actions taken have been increased. It is essential to consider that many measures taken were based on suggestions developed on pattern recognition. Besides, this user-friendly software, with innovative modules, improves employees' participation in NC reporting. It may be concluded that this solution enables important principles of QM: participation of employees and evidence-based decision making for quality managers.

All companies have introduced, implemented and certificated QMS according to ISO 9001:2015. Data where the correlation between NCs and sections of ISO 9001:2015 standards were established (Table 1). This correlation table allows quality managers to track back all NCs and have clear managerial implications for future inner and external audits.

Table 1. The number of NCs detected six months before software implementation and six months after software utilisation (NCs) is related to specific ISO 9001: 2015 sections**.**

Subsections of the ISO 9001:2015 standard	Before software utilization			After software utilization		
	SME 1	SME 2	SME 3	SME 1	SME 2	SME 3
4.1	0	0	0	0	0	0
4.2	0	0	1	2	1	3
4.3	2	2	2	3	3	3
4.4	2	1	2	1	2	3
5.1	0	0	0	0	0	0
5.2	0	0	0	0	0	0
5.3	2	2	3	3	3	4
6.1	2	2	3	3	3	4
6.2	3	3	2	4	4	3
6.3	0	0	0	0	0	0
7.1	0	0	0	0	0	0
7.1.1	0	0	0	0	0	0
7.1.2	0	0	0	0	0	0
7.1.3	2	3	3	4	3	4
7.1.4	0	0	0	0	0	0
7.1.5	1	1	2	3	2	3
7.1.6	0	0	0	0	0	0
7.2	1	1	3	2	2	2
7.3	0	0	0	0	0	0
7.4	0	0	1	0	0	0
7.5	2	2	1	0	0	0
8.1	0	0	0	0	0	0
8.2	2	2	0	0	0	0
8.3	0	0	2	0	0	0
8.4	2	3	1	4	3	6
8.5	4	7	4	8	8	7
8.6	2	1	1	2	1	0
8.7	4	4	3	7	6	5
9.1	2	2	2	1	2	2
9.2	1	2	2	2	2	1
9.3	2	2	3	2	2	2
10.1	0	0	0	0	1	0
10.2	2	1	2	0	0	0
10.3	0	0	0	0	0	0
TOTAL	38	41	43	51	48	52

Applying the software makes it possible to connect NCs with specific sections of the ISO 9001:2015 standard. Each company could have evidence of their data and define managerial actions according to the detected NCs primary sources. According to Table 4, it could be observed that most NCs could be connected with sections 8.7 and 8.5, but also significant NC number is related to 6.2.

To further extend the case study and consider the developed solution's performance, tests were performed to compare the developed solution with the possible solutions based on affordable technologies, including PHP, Apache server, MySQL and MariaDB. The authors tested the solutions on the identical infrastructures, which included servers for data storage with structures based on technologies MySQL/Apache/PHP, MariaDB/Apache/PHP, and MongoDB/Node.js/Express.js, and remote users presentation tiers with structures based on an application of HTML/CSS, HTML/CSS, and Angular, respectively. Testings reflected the most realistic possible scenarios to determine which technologies best performance in terms of forwarding queries and data retrieval from the databases.

Different NCs query workloads were created to test the previously used solutions' databases and current solution responsiveness. Each benchmark test was performed under the same quality manager user credentials, applying the default database settings.

First of all, there were three scenarios, including data insertion, modification, and selection. The first scenario is used to test the insertion agility for a more extensive set of data objects in a specific request, the second scenario to test the modification agility and the third scenario to test selection agility. Each test scenario was performed five times for different query quantities so that a mean value was calculated for each test type. The procedure was repeated due to variations that may occur during the execution of the tests. The tests contained syntax and structure, as shown in Table 2.

Table 2. *Insert, Update* and *Select* queries per second for each considered technology

MongoDB *Insert* syntax sample	**MariaDB/MySQL *Insert* syntax sample**
db.nonconformity.insertMany([{ "_id" : 1001, "mark" : "1657774A", "part name" : "Bumper", "quantity" : 20, "description" : "Rear bumper dimension mismatch", "placement" : "Assembly machine", "selected disposition" : "Alternative use", "disposition description" : "use NC products for a purpose other than originally defined", "production date" : new Date("2019-05-	INSERT INTO nonconformity VALUES (1001, '1657774A', 'Bumper', 20, 'Rear bumper dimension mismatch', 'Assembly machine', 'Alternative use', 'use NC products for a purpose other than originally defined', '2019-05-10')

10") }]);	
MongoDB *Update* syntax sample	**MariaDB/MySQL *Update* syntax sample**

db.nonconformity.update(
{ _id: 1001 }, // specifies which document to update
{
$inc: { quantity: 25 }, // increments the field value
$set: { // replaces the field value
"selected disposition" : "Return to the supplier",
"disposition description" : "Products have to be returned to the supplier since they are damaged."
}
}
)
	UPDATE nonconformity
	SET quantity = quantity + 5
	selected disposition = "Return to the supplier",
	disposition description = "Products have to be returned to the supplier since they are damaged"
	WHERE _id = 1001

MongoDB *select* syntax sample	**MariaDB/MySQL *select* syntax sample**
db. nonconformity.find({})	SELECT * FROM nonconformity

After preparing the test conditions and the tests' realisation, all three considered scenarios results were determined (Table 3).

Table 3. Queries per second for each considered technology

***Insert* queries**						
Previous technologies	**500**	**1000 q**	**2500 q**	**5000**	**7500**	**10000**
MySQL/Apache/PHP	0.0800	0.1638	0.4019	0.8014	1.2037	1.6027
MariaDB/Apache/PHP	0.0692	0.1439	0.3479	0.6931	1.0385	1.3846
MEAN	0.0224	0.0660	0.2323	0.3671	0.6284	0.9271
***Update* queries**						
Previous technologies	**500**	**1000**	**2500**	**5000**	**7500**	**10000**
MySQL/Apache/PHP	0.0697	0.1552	0.3873	0.8789	1.4402	2.0828
MariaDB/Apache/PHP	0.0783	0.1445	0.2722	0.3427	0.5177	0.6900
MEAN	0.0106	0.0525	0.2023	0.3254	0.3677	0.4368
***Select* queries**						
Previous technologies	**500**	**1000**	**2500**	**5000**	**7500**	**10000**
MySQL/Apache/PHP	0.0394	0.0732	0.1965	0.3943	0.6011	0.7999
MariaDB/Apache/PHP	0.0306	0.0655	0.1696	0.3385	0.5156	0.6826
MEAN	0.0037	0.0328	0.1116	0.1832	0.3110	0.4597

The tests introduced in this part of the study have been performed on a single server, but things might look different with data shared across clusters. This fact should be taken into account in future testing. Table 3 shows that the solution based on MongoDB has higher velocity when it comes to data insertion, modification, and retrieval compared to the solutions based on MySQL and MariaDB, mainly when dealt with a considerable amount of data. The increase in time for all three types of solutions DBMS seems to be linear. In the scenarios and circumstances covered in this study, the authors discovered that by switching from MySQL and MariaDB technologies to MongoDB technology, it is possible to get a significantly faster database with a relatively similar structure.

4. DISCUSSION

This paper is constituted on the I4.0 research starting from quality objectives to achieve conformity related to specifications, variations reduction, waste reduction, defects prevention, alignment between strategy and operation enhancement, efficiency and effectiveness of equipment and operations enhancement.

The presented software included some demands and unique features that differ it from similar solutions, primarily in the module where the: 1) Android Sensor Framework employed sensors from mobile platforms, that also the authors of this paper used; 2) novel RNN model could effectively analyse possible NCs, as sequential data determined corrective action, based on the knowledge about previously recognised NCs; and 3) authors enabled mobile platform to collect data from other sensors and IoT. It ensures that this solution surpasses similar products, bringing additional value to organisations. The presented solution enabled identifying products or resources, turning the mobile platform into a barcode reader, enabling full reporting traceability. When NC product or situation accrued, established algorithm forwarded task to dedicated quality manager suggesting possible actions. The authors implemented a module for RNN to detect possible patterns for corrective actions. This module will enable the responsible person to use some defined patterns or decide using suggestions or making entirely new actions. Besides, the solution could help define the same actions, such as rework, repair, permissions, corrections, and scrap.

A fundamental novelty, which is presented in this paper, refers to integrating research in QC, management, and software engineering. The developed software solution is intended to be used for affordable identification and reporting of NC with the possibility to integrate other software modules for quality analysis, problem-solving, corrective/preventive actions, and using a high level of applied methods (machine learning and artificial intelligence optimisation methods).

In addition, this paper indicates that small, affordable solutions developed to be user-friendly could incorporate some of the main principles of QM, such as employee engagement. In addition, the use of the MEAN stack provides an improved possibility for pattern recognition and fulfilment of other principles of QM, such as improvement and evidence-based decision making.

5. CONCLUSION

The amount of real-time data accumulated from multiple sources in production organisations is steadily increasing. If this data is stored, there is a tremendous opportunity to facilitate information flow and improve production processes with big data analytics and the right decisions. Therefore, this study's core premise is that one of the possible fundamental steps towards the I4.0, and subsequently, Q4.0 concepts incorporation, is to deploy mobile applications to enhance QM and production output. Accordingly, this study proposes a specialised role-based mobile application with multiple interfaces divided by roles that can be utilised to report real-time NCs and gain data-driven insight into subsequent production defect and root cause detection, defect mapping, machine failure, and downtime reduction.

As NCM represents one of the essential tasks of QM, it is necessary to acquire and use ICT to facilitate information and enable the implementation of effective proactive and corrective QM measures in real-time. Along with identification, documentation of NC has emerged as a problem. Solutions on this topic from broad literature are mainly based on traditional measures and procedures for solving NC and are usually being taken only by QM representatives and require a significant amount of time. Some of these dilemmas could be untangled by the convergence between Quality, I4.0, and IoT. Innovative software solutions could contribute to more advanced NCM.

The software solution brings benefits for both employees, managers and stakeholders through (1) involvement of all employees; (2) digitalisation and improvement of existing NC reporting systems; (3) improvement of NC culture; (4) better understanding and measurement of employer contribution to NCM; (5) making the technology ease of use both affordable and suitable for broader industry audience (the source code of a demo version, is publicly available on the GitHub repository: https://github.com/cqm-quality-center/nonconformity.

Finally, the developed solution is implemented in 3 SMEs. Initial results show several benefits in increasing NC detection, reporting, time, and increasing participation of employees number of preventive and corrective actions and improved QM system as a whole. The number of corrective and preventive actions was taken based on the assistance of the RNN module. All NCs were related to specific sections of ISO 9001:2015 standards so that quality managers and managers in the companies could have insight into the sources of the issues and the foundation for defining different managerial actions.

The system could be upgraded and expanded in many different directions, such as development modules for documentation management or advanced system image recognition (as part of QC) to support and interconnect with other systems (safety, environment management).

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