Error Text Codes Recognition from Information Display in Industrial Production Equipment

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***Abstract*—CNC display (Computer Numerical Control)is an important source of information on industrial production equipment operation (e.g., it shows errors in real-time). In this paper, we consider the direct monitoring problem for a CNC display to automatically detect error codes and analyze their sequences. We present our pilot service implementation, which uses real-life production equipment—a VARIA machine with CNC SINUMERIK 840D sl system.**

I. Introduction

Nowadays, there is a lot of visual data surrounding human. In particular, a lot of information is offered on digital billboards [1] for advertising on cars and commercials. In most cases, it contains contact telephone numbers and addresses. A person cannot quickly record or save information from such autonomous data presenters, because of the speed of displaying the advertisement. To solve this human perception problem, various external devices could be used that can recognize visual information, analyze it in the dynamic form, and provide its analytics to the user in a convenient form, e.g., as it happens with circular traffic sign detection and recognition [2].

In this paper, we consider the service that uses a camera for monitoring a SINUMERIK CNC information display. The CNC display shows messages (error codes) on the production equipment operation and status. The service recognizes error codes (mapping to text description), collect the errors in a log, and recognizes causal chains of semantically related errors. The service provides the operator with error/even description as well recommendations (from the operation manual) for resolving specific errors. Basically, this property makes the service “smart”, following the Ambient Intelligence (AmI) technology [3].

Existing monitoring system typically do not use automatic reading from the CNC display. They are oriented on direct access to the embedded control system. First, the direct access is expensive since it requires rent payment for the access. Second, the access makes certain workload to the embedded control system, which can potentially lead to performance loss and even faults in the production operation.

The rest of this short paper is organized as follows. Section II defines the message recognition problem on CNC display to detect text error codes and to analyze their relationship. Section III describes the system design and use cases. Section IV shows our pilot application. Section V summarizes the achieved results.

II. Problem Statement

The paper considers the problem of obtaining and analyzing error codes from a CNC machine. The factory on which the machine is installed requires constant monitoring of the state of the machine during operation, for timely detection of: breakdowns, errors. As a rule, the CNC carries out this control and the operator does not need to stop the machine to check any technical unit. Most SINUMERIK CNC machines are equipped with a special control panel, which is a monitor with control buttons, which allows the operator to quickly obtain the necessary information. The CNC screen contains a lot of useful information about the current operation of the machine: current indicators of the temperature of the machine, engine speed, CNC errors. Since during intensive work of the machine the data is constantly changing and you need to remember them for subsequent analysis.

At the moment, the main way to receive data from the machine is to connect to the CNC via a special bus and receive data using existing interfaces. To use this method, the machine requires the purchase of a special license, which will cost the factory very expensive. There is also the possibility that data unloading can affect the operation of the central processor, which can cause defective processing of the part. Modern CNCs support logging, but due to problems associated with access during operation, the receipt of such data can occur during machine shutdown, which can be from 1 hour to 14 days [4] from the time the machine started to work.

Tracking errors of the machine, is an effective measure of control over the work, as machines equipped with CNC have a large number of sensors that monitor the work machine.

Manual error analysis is the main way to monitor machine status before stopping or shutting down. This analysis is carried out by the technical operator of the machine, which spends a large amount of its time on obtaining data, finding descriptions of errors of interest, identifying regular and sequential errors. The SINUMERIK 840D sl CNC error manual has about 1 million error codes, which imposes the technical operator on the problem of quickly finding and receiving descriptions and methods for fixing errors.

The emergence of critical situations associated with the operation of the machine is accompanied by a sequence of some errors. Most repetitive problems with the machine can be avoided by monitoring real-time published errors and warning the operator. Manual mode of tracking errors in real time is not possible, since the speed of one error can be about 2 seconds and errors can be displayed one after another, as well as loop

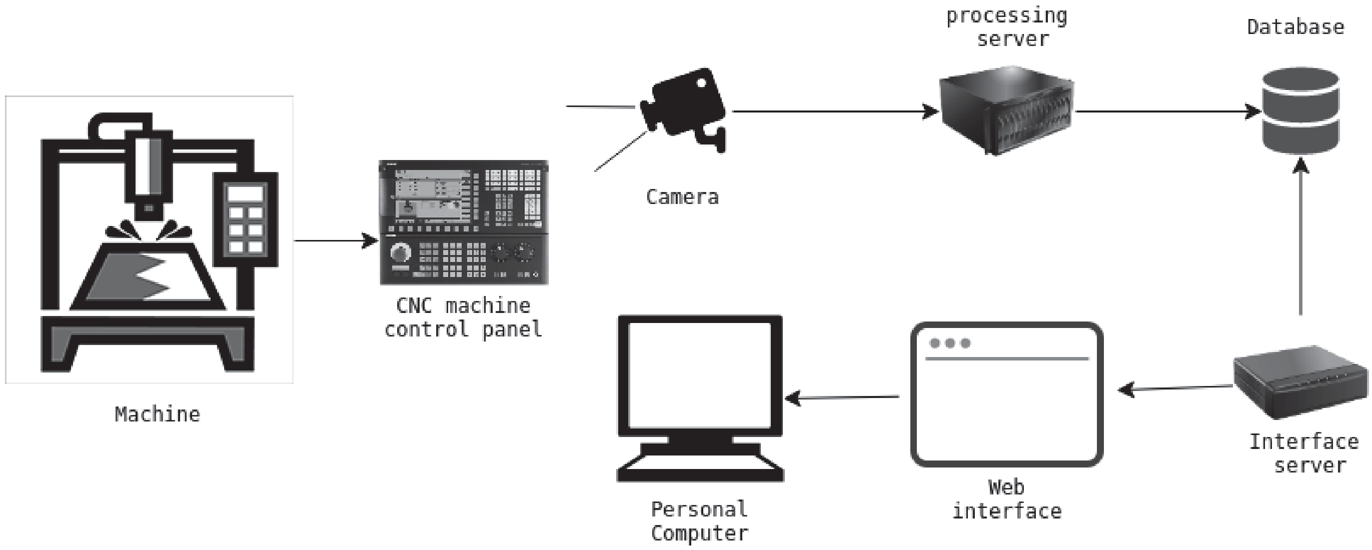


Fig. 1. Service architecture

and new ones can be added. Since the operator needs not only to write them down, but also to find a description and analyze.

To solve this problem, an external mounted system is proposed including: a camera aimed at the screen and computing devices for processing, storage and display of the results. Existing programs and methods [5] implement the text recognition on screen with a high recognition percentage and short operating time, which will allow you to receive machine error codes in real time. Using an external hinged system allows you not to interfere with the operation of the CNC and to exclude the possibility of defects on the parts due to the fault of the service. The use of screen recognition technology in a factory is carried out for the first time and requires solving a number of problems related to the placement conditions of the camera relative to the screen, environmental conditions and factors affecting the camera.

The operator will be provided with an interface in which errors will be published, and a full description will be provided. Existing analysis systems allow you to track existing errors, as well as some of them provide the ability to conduct dependencies between various errors and determine their relationship. The service being developed will track predefined error chains to notify the operator of their occurrence and provide a pre-arranged plan by the technical operator to prevent breakage and machine shutdown.

This service is designed to monitor a VARIA machine with SINUMERIK 840D sl [6] CNC installed at the Petrozavodskmash factory. The service will allow you to monitor the condition of the machine in real time without monitoring by workers. In the event of an emergency, the service will notify the operator of the problem. This service can be used on any CNC machine with a screen for monitoring machine performance. The service automates machine monitoring and reduces the unexpected incapacitation of expensive equipment

III. System Design

Figure 1 shows the architecture of the implementation of the service being developed. To collect data, a camera is used aimed at the monitor of the machine control panel. The resulting video stream is sent to the processing server, where it is processed and the received error codes are recorded in the database. The user interacts with the scripts provided to him through the web interface. The presented architecture allows not to limit the place of the user of the service to a certain territory around the machine, which allows increasing mobility and scalability. The user of the service can monitor several machines, and in case of problems inform local technical groups and, based on the testimony of the service, give recommendations on servicing or fixing problems with the machine.

In most CNCs, to save space on the information screen, published errors are encoded in numerical form. For each brand of CNC, there is its own error guide in which the error number is associated with its description and remedies. An example error code description is shown in Fig. 3. This description includes the following.

- *Parameters:* show what data can be seen when looking at a detailed description of errors in the CNC system.
- *Definitions:* describe the problem that causes this error.
- *Reaction:* defines the reaction of the system to the error,
- *Remedy:* describes how to fix the error,
- *Program Continuation:* determines how the system can continue to work.

Figure 2 shows a diagram of the data that the user receives when working with the service. The service provides three types of use cases. The first type is the use to get the current CNC machine error. The service will present the current error code and a photograph of the code made on the machine

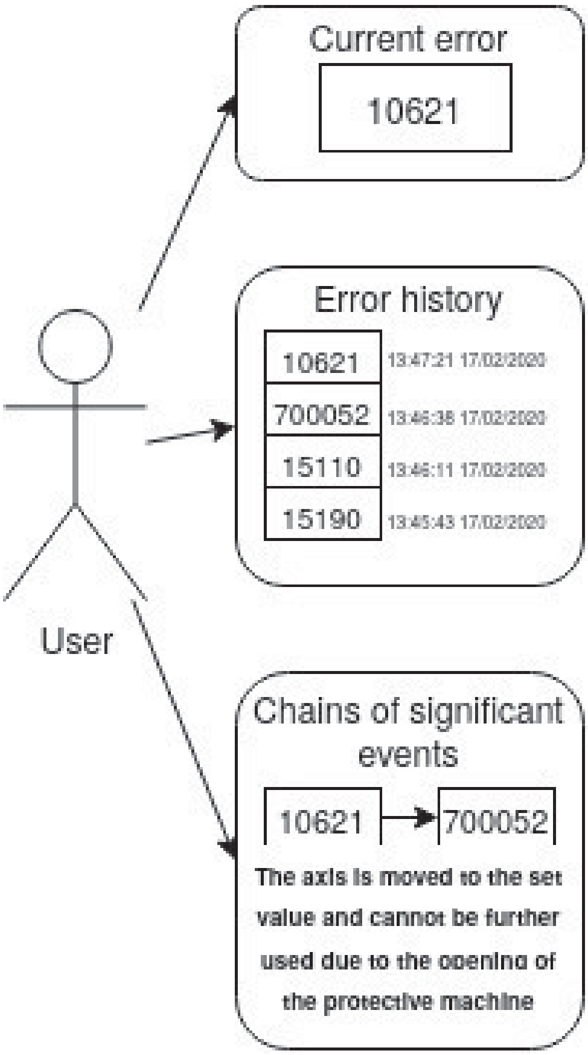
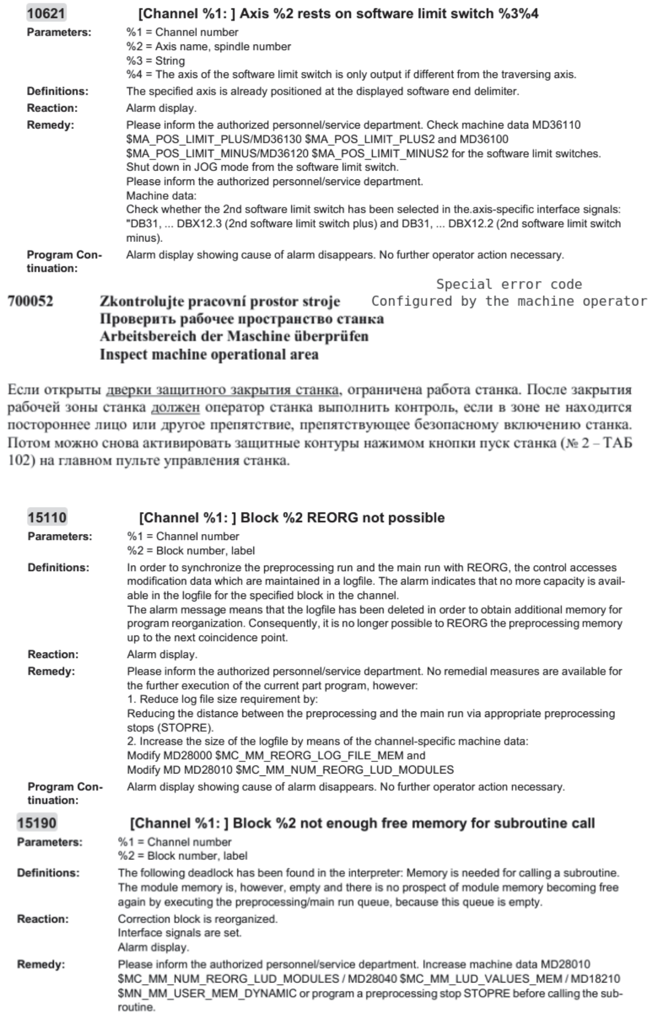


Fig. 2. Options for using the service by the user



10621 **[Channel %1:] Axis %2 rests on software limit switch %3%4**

Parameters: %1 = Channel number
%2 = Axis name, spindle number
%3 = String
%4 = The axis of the software limit switch is only output if different from the traversing axis.

Definitions: The specified axis is already positioned at the displayed software end delimiter.

Reaction: Alarm display.

Remedy: Please inform the authorized personnel/service department. Check machine data MD36110 $MA_POS_LIMIT_PLUS/MD36130 $MA_POS_LIMIT_PLUS2 and MD36100 $MA_POS_LIMIT_MINUS/MD36120 $MA_POS_LIMIT_MINUS2 for the software limit switches.
Shut down in JOG mode from the software limit switch.
Please inform the authorized personnel/service department.
Machine data:
Check whether the 2nd software limit switch has been selected in the.axis-specific interface signals: "DB31, ... DBX12.3 (2nd software limit switch plus) and DB31, ... DBX12.2 (2nd software limit switch minus).

Program Continuation: Alarm display showing cause of alarm disappears. No further operator action necessary.

Special error code
Configured by the machine operator

700052 **Zkontrolujte pracovní prostor stroje**
Проверить рабочее пространство станка
Arbeitsbereich der Maschine überprüfen
Inspect machine operational area

Если открыты дверки защитного закрытия станка, ограничена работа станка. После закрытия рабочей зоны станка должен оператор станка выполнить контроль, если в зоне не находится постороннее лицо или другое препятствие, препятствующее безопасному включению станка. Потом можно снова активировать защитные контуры нажимом кнопки пуск станка (№ 2 – ТАБ 102) на главном пульте управления станка.

15110 **[Channel %1:] Block %2 REORG not possible**

Parameters: %1 = Channel number
%2 = Block number, label

Definitions: In order to synchronize the preprocessing run and the main run with REORG, the control accesses modification data which are maintained in a logfile. The alarm indicates that no more capacity is available in the logfile for the specified block in the channel.
The alarm message means that the logfile has been deleted in order to obtain additional memory for program reorganization. Consequently, it is no longer possible to REORG the preprocessing memory up to the next coincidence point.

Reaction: Alarm display.

Remedy: Please inform the authorized personnel/service department. No remedial measures are available for the further execution of the current part program, however:
1. Reduce log file size requirement by:
Reducing the distance between the preprocessing and the main run via appropriate preprocessing stops (STOPRE).
2. Increase the size of the logfile by means of the channel-specific machine data:
Modify MD28000 $MC_MM_REORG_LOG_FILE_MEM and
Modify MD MD28010 $MC_MM_NUM_REORG_LUD_MODULES

Program Continuation: Alarm display showing cause of alarm disappears. No further operator action necessary.

15190 **[Channel %1:] Block %2 not enough free memory for subroutine call**

Parameters: %1 = Channel number
%2 = Block number, label

Definitions: The following deadlock has been found in the interpreter: Memory is needed for calling a subroutine. The module memory is, however, empty and there is no prospect of module memory becoming free again by executing the preprocessing/main run queue, because this queue is empty.

Reaction: Correction block is reorganized.
Interface signals are set.
Alarm display.

Remedy: Please inform the authorized personnel/service department. Increase machine data MD28010 $MC_MM_NUM_REORG_LUD_MODULES / MD28040 $MC_MM_LUD_VALUES_MEM / MD18210 $MN_MM_USER_MEM_DYNAMIC or program a preprocessing stop STOPRE before calling the subroutine.

Fig. 3. Error code description

monitor, and the service also provides a written description of the error code, taken from the directory [7]. Existing CNC systems account for up to a million error codes and showing the error description will save the user from searching for information and focus on the problem of the machine. There are also error codes not included in the description of the diagnostic manual. Each factory that has SINUMERIK CNC can independently program these error codes to suit their needs and conditions.

The second type is saving past errors. The user can quickly see machine error history to determine the current state of work and track critical failures. The third type is the search for a chain of significant events. In various situations, the CNC of the machine can produce a certain chain of errors. The user can manually set the necessary chains. This will quickly identify the cause of the problems and fix them. Figure 2 shows the tracking of such caps using the example of SINUMERIC 840D sl CNC rowing errors.

Figure 4 shows an algorithm of the first type of use scenario - error recognition on the machine screen. The received video from the camera is divided into frames and each frame is analyzed. There is an area in which the CNC system publishes the last current error. Perspective image conversion is applied to this area to standardize the image with further text recognition. To improve recognition rates on the transformed area, filters are applied that normalize the value of the image pixels and change the threshold value, as well as remove various noises. The resulting image is used for text recognition [8]. The user is provided with recognized text and a standardized and unfiltered error image.

The resulting error code is saved with a timestamp for ranking when viewing the history and analysis to determine the error chains. Since an error can be recognized more than once, it is required to track error codes that are repeated and there are no other errors between them in a time series since the CNC system can cyclically display the same set of errors.

Problems and their solutions arising when using the camera as a data source are described in Table I.

Emerging service problems are associated with the use of a camera as an interface for receiving information. In the conditions of the factory, it is required to maintain it in a

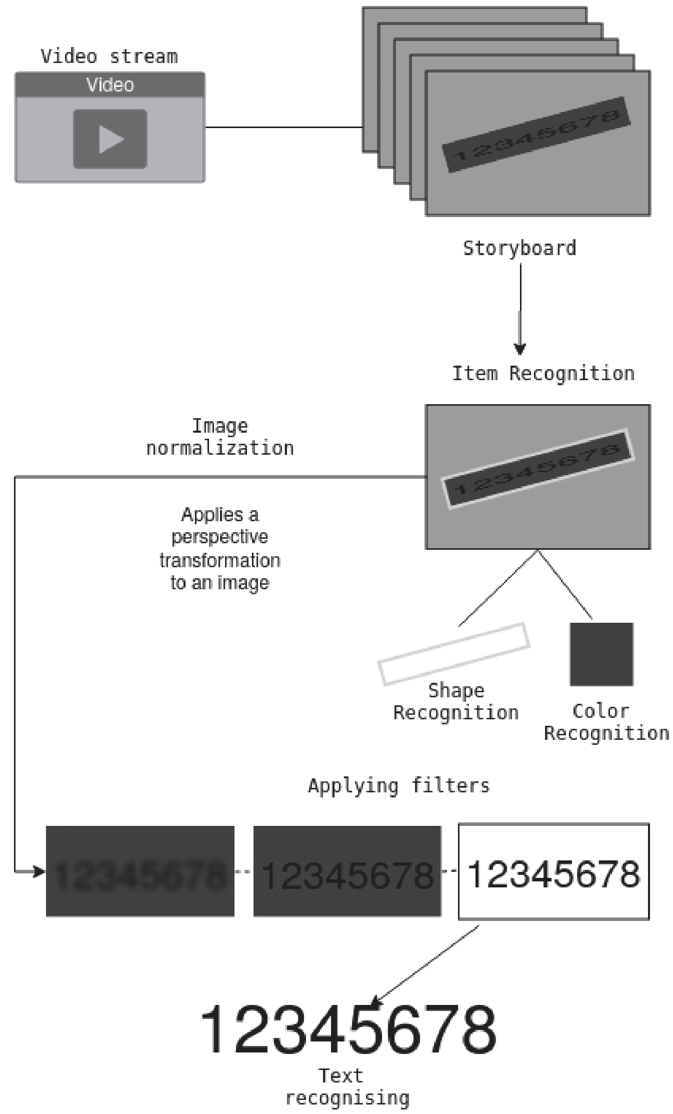


Fig. 4. Error recognition script

TABLE I. PROBLEMS DURING THE PRODUCTION EQUIPMENT OPERATION

Problem	Decision
The camera should not interfere with the operator when working with the machine remote control	The camera is located on the side of the screen, this solution allows you not to interfere with the operator but denormalizes the image
The camera lens may become dirty	A software check for lens contamination is required
Camera position can be changed	Requires additional check for camera downs when processing video
The screen image may vary depending on external lighting effects and screen features	Various specialized filters are required to standardize the resulting image

working condition. Although the camera is fixed, its position can be knocked down. Also, in the conditions of work at the factory, the camera lens can be coated with various substances: dust, metal grease or oil sludge. It is required to track these actions to notify the operator of the need to change the position of the camera or to clean the lens. This tracking allows you to quickly correct physical defects and constantly receive a suitable picture for further recognition.

Fig. 5. Machine stand emulator: front view

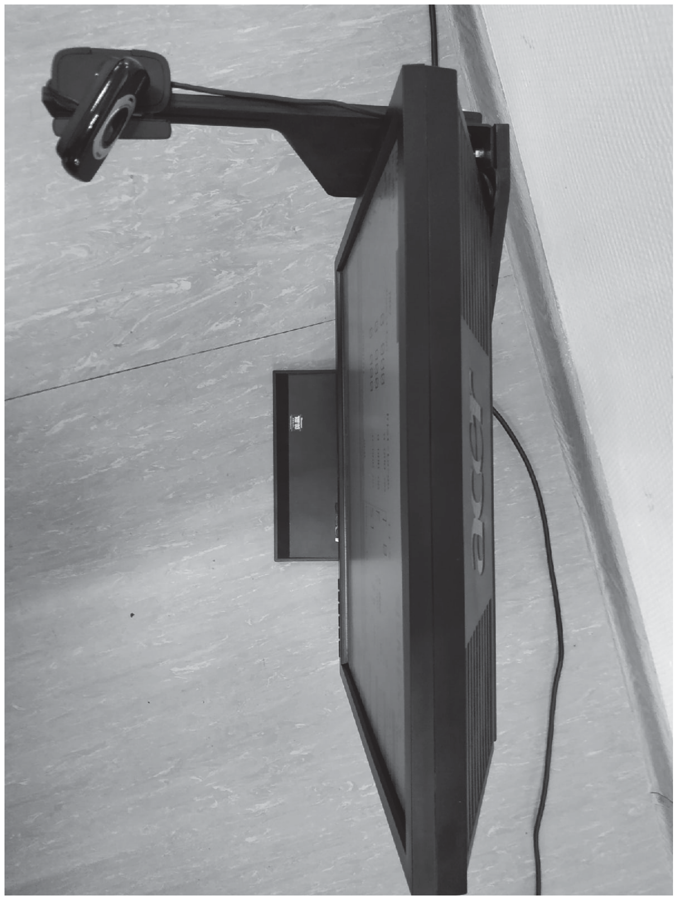


Fig. 6. Machine stand emulator: top view

The developed architecture allows you to quickly implement this service from existing solutions, components and libraries. Also, the solution is universal and requires a minimum change in the recognition of the necessary data when changing the recognition of machine error codes to any other information located on the information monitor of the CNC machine.

Fig. 7. Camera frame

Fig. 8. Camera frame with error area

IV. Pilot Application Case

For testing the demo service, an emulating screen monitor CNC SINUMERIC 840D sl was developed. The CNC monitor displays error codes that the developed system must be tracking. The monitor is emulated on a screen with a resolution of 1280x1024 and a diagonal of 19. A tripod is mounted on the monitor to place the camera on it. For testing, the Logitech c615 webcam is selected. The webcam is equipped with autofocus, which allows you to automatically focus on the CNC screen.

The camera is placed at least 10 centimeters from the edge of the screen, since during the testing of the CNC monitor, it was found out that due to viewing angles, to obtain an acceptable image, this distance is the minimum possible. A camera with an automatic focus allows you to get a clear picture, which improves the work for further algorithms. For a camera without autofocus, you will have to choose the optimal distance. Figures 5 and 6 show a stand with a tripod and a camera placed on it. The choice of tripod mounting location is because it should not interfere with the operator when working with the CNC screen.

In the area visible by the camera, the error code in full size should fall. If there is no error code, the system notifies the user of the need to check the camera position for shooting down. The system also takes into account that the machine does not work and the screen does not work, then the system notifies the operator of the turned-off machine.

Figure 7 shows the frame received by webcam [9]. Due to the location of the camera, this image needs to be brought in a horizontal orientation. Since the position of the camera may vary, it is not known how to properly normalize the image. To do this, the location of the error code is searched for on the image. This place is visually confirmed by two factors: red background and a rectangular area. This search is carried out using the OpenCV library and the moments and findContours methods. Figure 8 shows a camera image with a marked error location area.

Using the obtained coordinates of the quadrangular region of the error location, Fig. 9 a) is normalized using the OpenCV library and the warpPerspective method. Normalization by this method cuts off the selected area and enlarges the image in size, which negatively affects its quality. After conversion, it is necessary to reduce the image to its initial size. There is also a method for normalizing without cropping the image. For this purpose, the target points should be shifted [10].

Filters from the OpenCV library are applied to the resulting image. There are several filtering options. See Section III for the standard in bringing the image to the best possible recognition accuracy [11].

The following filter sequence can also be applied: cv2.cvtColor (BGR2GRAY), cv2.normalize, cv2.inRange, obtaining opposite shades. To get the best result, you can use the normalization method at different positions of the light source [12]. Result in Fig. 9 b) is recognized using the pytesseract library [13]. At the moment, the demo service allows you to recognize the error code on the screen and present it to the user without any additional settings.

Service metrics are presented in Table II. These metrics show that the service was implemented in Python3 using the libraries cv2, pytesseract, PIL, numpy. These libraries are popular among developers working with images and allows you to use the many already implemented image transformations, thereby increasing productivity and reducing the amount of code required for writing. The service code is written using the class structure, which will allow you to quickly change the necessary functions to use when recognizing other information on other machines.

TABLE II. Demo service metrics

Metric Type	Metric value
Programming language	Python3
Main libraries used	cv2 [14], pytesseract, PIL, numpy
Number and type of classes	2 classes, Webcam - for working with the camera, Img - for working with the image
Number of lines of code	300
Number of functions	13, normalizes the image, filters the image, gets the coordinates of the contour with an error ....

The demo service was launched on a computer with the following characteristics: Intel® Core i7-4700MQ CPU @

a) b)

Fig. 9. Image enhancement for recognition

2.40GHz x 8, 12 gigabytes of RAM. The processor workload by the program during the operation was estimated at 20-25% and RAM 100-150 megabytes. This configuration allows you to find and recognize error codes in one frame in less than 0.2 seconds. This workload shows that this service can be used on low-performance computers. The accuracy of recognition by the service of error codes varies at the level of 80-95% depending on external factors such as lighting and slight contamination of the camera lens.

The cost of service components, including a computer, a camera and additional means of clearing, are estimated at 500 dollars. The cost of a license for direct access to the CNC machine is estimated at 10,000 dollars. The solution being developed is many times cheaper than its competitor and will have such additional functions as providing error descriptions and tracking error chains. The implementation of additional functions is the next stage in the development of the service and will allow the operator to provide quick and necessary information on error correction methods and to warn about already known error scenarios received before a machine breakdown.

V. CONCLUSION

This work-in-progress paper considers the problem of display monitoring to detect error codes and analyze their sequences. We presented a demo service based on real-life production equipment—VARIA machine with CNC SINUMERIK 840D sl system. The service can work autonomously using small computing resources. The architecture of the service allows you to quickly deploy this service and adapt it for use on any SINUMERIK CNC, as well as on other CNCs containing an information screen. The information obtained allows you to automate the work of the machine operator and to protect the machine from breakage and workpieces from defects.

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REFERENCES

[1] T. Intasuwan, J. Kaewthong, and S. Vittayakorn, "Text and object detection on billboards," in *2018 10th International Conference on Information Technology and Electrical Engineering (ICITEE)*, 2018, pp. 6–11.

[2] S. K. Berkaya, H. Gunduz, O. Ozsen, C. Akinlar, and S. Gunal, "On circular traffic sign detection and recognition," *Expert Systems with Applications*, vol. 48, pp. 67–75, 2016.

[3] D. Korzun, E. Balandina, A. Kashevnik, S. Balandin, and F. Viola, *Ambient Intelligence Services in IoT Environments: Emerging Research and Opportunities*. IGI Global, 2019.

[4] Q. Zhang, S. Liu, C. Duan, and Y. Zhu, "The architecture of reliability information system for cnc machine tool in concurrent engineering," in *Materials Science Forum*, vol. 471. Trans Tech Publ, 2004, pp. 603–607.

[5] X. Xu, J. Zhou, and H. Zhang, "Screen-rendered text images recognition using a deep residual network based segmentation-free method," in *2018 24th International Conference on Pattern Recognition (ICPR)*, 2018, pp. 2741–2746.

[6] J. Jiang, C. Kong, X. Zhou, W. Liu, and Q. Niu, "Research on key technology of cnc machine tool intelligent monitoring system for smart factory," in *Advances in Manufacturing Technology XXXI: Proceedings of the 15th International Conference on Manufacturing Research, Incorporating the 32nd National Conference on Manufacturing Research, September 5–7, 2017, University of Greenwich, UK*, vol. 6, 2017, p. 142.

[7] *Diagnostics Manual SINUMERIK 840D sl/ 840Di sl/ SINAMICS S120*, Siemens AG, 3 2009.

[8] Y.-M. Su, H.-W. Peng, K.-W. Huang, and C.-S. Yang, "Image processing technology for text recognition," in *2019 International Conference on Technologies and Applications of Artificial Intelligence (TAAI)*, 2019, pp. 1–5.

[9] H. Miura, S. Ozawa, T. Matsuura, K. Yamada, and Y. Nagata, "Proposed patient motion monitoring system using feature point tracking with a web camera," *Australasian physical & engineering sciences in medicine*, vol. 40, no. 4, pp. 939–942, 2017.

[10] "Opencv warpperspective, warpaffine whole image and destination result image size," May 2016. [Online]. Available: http://pavelk.ru/opencv-warpperspective-bez-obrezki-whole-image-i-razmer-rezultata-destination-result-size

[11] M. J. Kumar, "Scene text segmentation and recognition by applying trimmed median filter using energetic edge detection schemes and ocr," *Journal of Network Communications and Emerging Technologies (JNCET) www. jncet. org*, vol. 7, no. 12, 2017.

[12] G. D. Finlayson, B. Schiele, and J. L. Crowley, "Comprehensive colour image normalization," in *European conference on computer vision*, 1998, pp. 475–490.

[13] R. Smith, "An overview of the tesseract ocr engine," in *Ninth International Conference on Document Analysis and Recognition (ICDAR 2007)*, vol. 2, 2007, pp. 629–633.

[14] H. Singh, "Advanced image processing using opencv," in *Practical Machine Learning and Image Processing*. Springer, 2019, pp. 63–88.