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PREDICTIVE INTELLIGENT MAINTENANCE CONTROL USING AUGMENTED REALITY

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Abstract:

Modern manufacturing industry is currently facing significant challenges regarding the concept of Industry 4.0. The promise of increased productivity and flexibility in manufacturing processes cannot be achieved without implementation of systems and advance methods based on smart technologies. Implementation of Industrial Internet of Things (IIoT), Condition Monitoring, Big Data, Cloud computing, virtual and augmented reality in maintenance processes will significantly increase the effectivity and quality of manufacturing processes as well as eliminate the human factor. Under this perspective, cyber–physical systems can be accessible from remote location; process parameters can be visualized at real time and prediction of unexpected production stop due to machine breakdown will be significantly reduced. The paper deals with the development of effective approach to real-time process control using parameters visualization of manufacturing process with the use of augmented reality smart glasses. Collected data from condition monitoring sensors from electric monorail system are evaluated in real time and visualized in the field of view of maintainer. Critical values from field of sensors are highlighted and enable to predict manufacturing breakdown. On real example from automotive industry will be demonstrated the signification and effectivity for maintenance of electric monorail system and potential for application in different types of modern industrial processes with the focus on rule-based intelligent predictive maintenance control.

Keywords:

Industry 4.0, intelligent control, smart maintenance, augmented reality, condition monitoring, cyber-physical systems.

ACM Computing Classification System:

Embedded and cyber-physical systems, Real-time systems, Communication hardware, interfaces and storage.

Introduction

Industry 4.0 represents the fourth industrial revolution in manufacturing industry with the focus on the establishment of intelligent product and production processes. The promise of increased productivity and flexibility is a current driving force at the heart of the industry development representing the realization of large-scale changes in current industrial manufacturing. These changes include automation, digitalization, intelligent control methods and integration of information and communication technologies (ICT) at all levels of prototyping, process control, maintenance and services. These challenges cannot be achieved without the implementation of systems and methods based on smart manufacturing and smart maintenance. Systems and methods such as Internet of Things, Cyber-physical systems, Big Data, Cloud computing, virtual and augmented reality refer to the methodology of Industry 4.0 to achieve demand of increased flexibility and performance of production. [1]

The internet of things (IoT) is an information network of physical objects (sensors, machines, car, buildings, and other items), that allows interaction and cooperation of these objects to reach common goals. Term IoT affects among others transportation, healthcare or smart homes, the Industrial Internet of Things (IIoT) refers to industrial environment. Application of IIoT provides to internet-enabled cyber-physical systems ability to connect to new interconnection technologies and applications. Based on this perspective, industrial cyber-physical systems can be accessible from remote locations, process data on them can be processed, transformed, analyzed and managed in distributed locations at real time. [1, 2]

Over the last years, the initiatives to apply smart manufacturing and maintenance methods and systems based on interoperability, virtualization, decentralization, modularity and real time data collection and analysis to improve performance, intelligence, cyber security and compatibility has increased dramatically.

Concept of smart manufacturing and maintenance referred to Industry 4.0 is characterized by and based on the following technologies (Fig.1):

a. *Autonomous Robot* that can interact with one another. These robots are interconnected so that they can work together and automatically adjust their actions to fit the next unfinished product in line. High-end sensors and control units enable close collaboration with humans.

b. *Big Data* - data collection and analysis refers to a large amount of diversified time series generated at a high speed by equipment. Smart manufacturing requires data to be collected and analysed at real time. Based on the information collected, real-time intelligent control and decision-making methods can be used for support of manufacture and maintenance processes.

c. *Cloud Computing* is shared pool of configurable computer system resources and higher-level services that can be rapidly provisioned over the internet.

d. *Industrial Internet of Things* refers to an industrial framework whereby large numbers of devices or machines that are connected and this enables intelligent industrial operations using advanced data analytics.

e. *Cyber security* with the increased connectivity and use of standard communications protocols that come with Industry 4.0, the need to protect critical industrial processes, the process of keeping every industrial layer, including SCADA servers, HMI, engineering workstations, PLCs, network connections and people guarded against cyber threats without impacting on operational continuity and the consistency of industrial processes.

f. *Augmented (AR) and Virtual Reality (VR)* technologies are increasingly being used in manufacturing processes. These use real and simulated objects and information to create a simulated environment and digital information that can be used to enhance the manufacturing and maintenance processes, qualification and eliminate the human factor.

The paper consists of three parts. The part 1 deals with problem formulation of current state of maintenance, industrial internet of things and industrial augmentation. The part 2 of the paper provides a description of the proposed approach and system implementation in terms of the hardware and software components. The part 3 deals with the case study of possibilities and new methodology of augmented reality in industrial application.

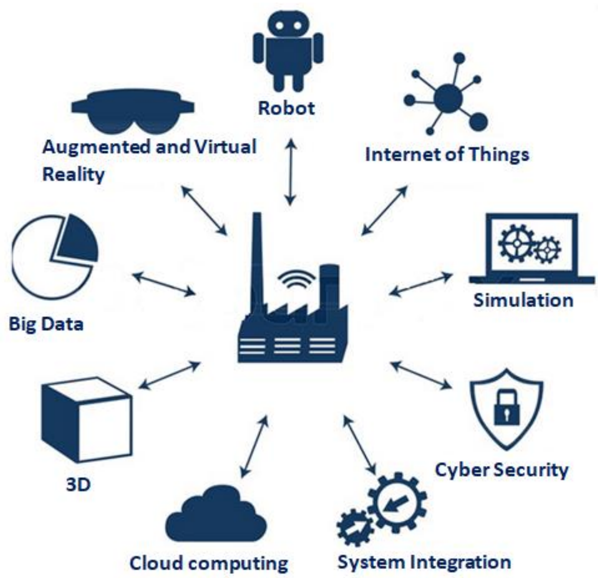

Fig.1. Basic scheme of the technologies in smart factory.

1 Problem Formulation

The paper proposes a new visualization approach of process equipment parameters in automotive manufacturing using augmented reality. This approach aims at providing support to the maintenance worker through visualization of different information, originating from condition monitoring system.

Maintenance is a strategic concern when developing and manufacturing a product. Breakdowns and unexpected production stops are expensive, because of financial and operating time losses. For product manufactures, preventive maintenance and asset repairs consume unncessary resources, operational and service cost, and present a serious impediment to efficient operations. [3, 5]

The term Industry 4.0 arises from the combination of new information technologies and data analysis with advanced fabrication techniques and processes. To accomplish demands of Industry 4.0, Industrial Internet of Things represents a superior approach that involves continually generating and transmitting machine behaviour data, capturing the data in a central repository and applying advanced big data analytics techniques to sort through massive amounts of data and identify important patterns to deliver predictive maintenance insights. This significant approach becomes relevant only in case of displaying the correct data in the correct place and it can lead to just in time maintenance and increase product uptime, improve asset efficiency and eliminate unnecessary repair costs. The key enabler for smart maintenance is the ability to interact with in real time, and expand the capabilities of the physical world through computation, digitalization and visualisation with digital content. Comparison of traditional and smart maintenance approach is listed in (Tab.1)

Augmented reality (AR) refers to a new generation of systems with integrated computational and visualisational capabilities that combines real and virtual objects in a real enviroment. Industrial Augmented Reality (IAR) applications are systems to be used in a product lifecycle process utilizing the concept of spatially aligned and interactive overlay of computer generated information in a working context. [2, 4]

In context of rule based predictive maintenance, the AR application implements three main functionalities:

- Support through the visualisation of different types of information, as assembly sequence, spare parts and data from condition monitoring system.
- Maintenance process information provision in real time through instruction list.
- One point maintenance lessons to support maintenance worker through virtual demonstration, videos and image.

Table 1. Comparison of maintenance approach.

Process	Traditional maintenance	Smart maintenance
Learning new technology	- Limited resources - Not up to date observations - Verbal guidance	- Learning by virtual and augmented reality - One point lesson - Digital guidance
Work execution	- Detailed work instruction missing - Paper documentation - Complicated remote worker assistance	- Real time support (text, voice, video) - Digital documentation - Hands free application - Online remote support
Work reporting	- Paper based orders and reports - Manual entry to company IT system	- Smart glasses connected to ERP System - Photo and video reports - Digital analysis

2 System Implementation

The proposed approached aims at providing intelligent predictive maintenance control through the visualization of different types of information using augmented reality. For effective Industrial augmented reality applications is essential to display real data in the correct place. In this context, following essential components are needed (Fig.2): [6]

- Application that contains applications logic and controls access to database.
- Tracking that determines position and orientation of user and objects.
- Interaction registers and processes user input.
- Presentation, that generates and presents the AR scene through 3D visualization.
- Context collects contextual data and makes it available to other subsystems.
- World model contains information about real and virtual objects in the user environment.

Interaction between real and virtual objects is perfomed through AR marker (tag) that enables to attach information to real world facilities, assets, and objects, to provide just in place data. Tag enables digital information to flow from existing systems, such as condition monitoring or SAP for asset management and performance data, into the real world. Collection of tags related by a physical area is defined as a workspace. Each workspace is identified by unique selector and is aligned with physical world by landmark.

Augmented reality applications in automotive industry focus on all processes relevant to maintenance. After analyzing the state of the art and processes directly on the production lines, the pilot project was selected for the visualization of the operating parameters, instruction list and one point lesson. Data from field of sensors (temperature, vibrations, etc.) installed on the car transport system engines are dynamically processed and displayed to the maintenance worker in order to detect anomalies and more accurately identify possible sources of problems. Maintenance instruction lists and one point lessons guide are loaded from SAP system in real time and displayed in the smart glasses.

In order to develop the application for the cases described above, the proposed IAR system makes use of the fog computing communications architecture depicted in (Fig.3). Fog computing extends cloud computing by moving part of the computational and communication capabilities of the cloud close to the sensor nodes. Such an approach makes it possible to minimize the delay, which is a critical factor in dynamic systems of expanded reality. No less important is the distribution of computational power.

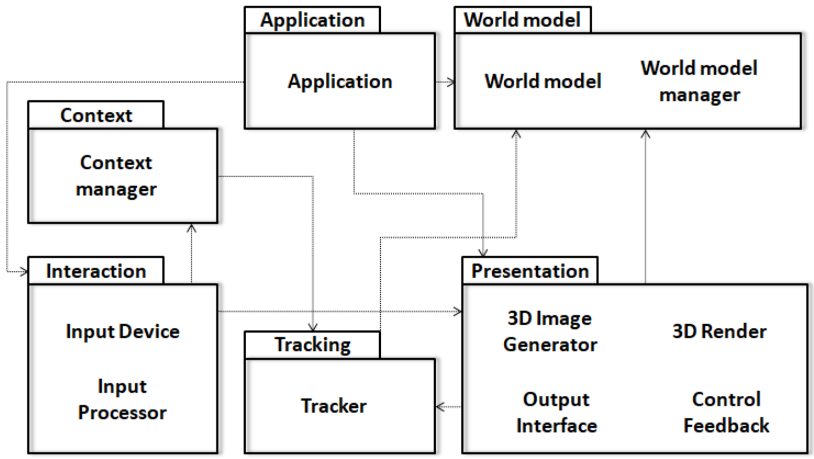

Fig.2. Reference architecture of IAR system.

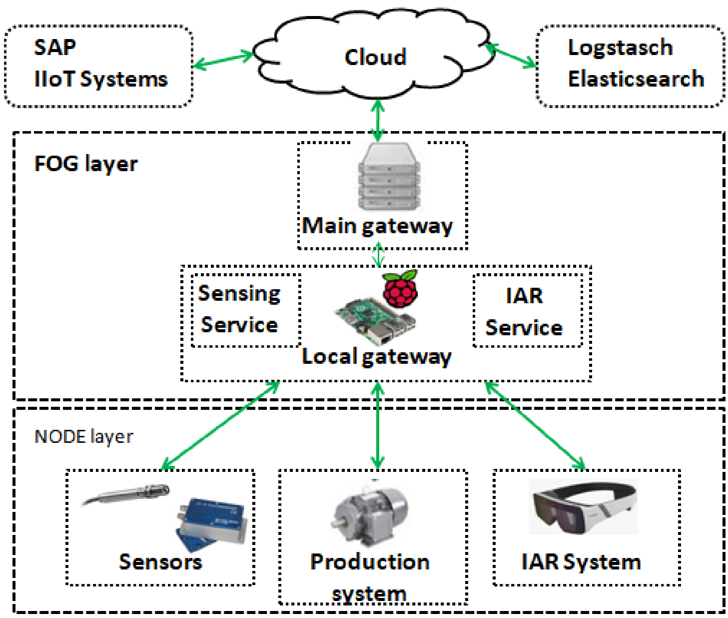

Fig.3. Fog computing communication architecture for IAR system.

The architecture of the proposed system is composed of the following layers: [4]

- Node layer includes all the IAR devices that interact with the services provided by the fog layer. The fog layer also exchanges data with sensor networks.
- Fog layer, which consists of dedicated computers that act as gateways and provides fog services.
- The cloud, which represents the place where the data is stored, analyzed and evaluated on receipt from multiple sources.

The communications between each IAR device and the fog layer are performed through Wi-Fi connections.

3 Case Study

The case study tested by this application originates the automotive industry maintenance and has been applied to the electric monorail system shown in (Fig.4) that transports car parts or bodies between assembly positions. An electric monorail system is a rail-bound type of conveyance with individually driven vehicle, which move independently on the closed rail system. This system consists of conductor rail, frame, engine, control unit, optical sensor and rolling wheel. Failure of any components in closed rail system cause interruption of production for several hours. [3]

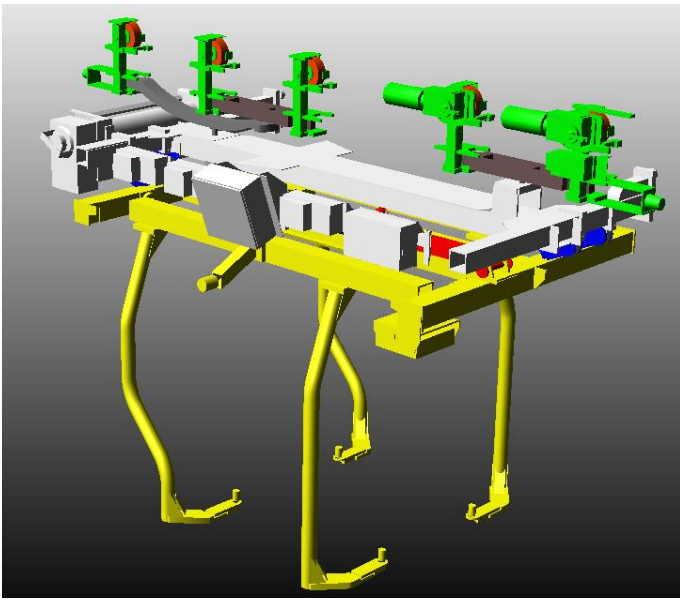

Fig.4. Electric monorail system.

To realize intelligent predictive maintenance control of electric monorail system using augmented reality, system according to the (Fig.3) was realized. The first layer represents smart glasses for augmented reality, electric monorail system and condition monitoring filed of sensors. The second layer is represented by Raspberry Pi 3 and the RAY-X datalogger. The third layer implementation enables device monitoring in real time, using an open Logstash server that allows data collection and transformation into JSON format and subsequent data transmission.

The search and analytics tool Elasticsearch enables you to search and analyze large amounts of data quickly and in real time. Subsequent visualization of operating statuses form condition monitoring, instruction lists and one-point lessons from SAP system is possible on a computer using the Kibana visualization program, or directly by using smart glasses for augmented reality. We propose the basic structure for intelligent predictive maintenance control using augmented reality according to the scheme shown in (Fig.5).

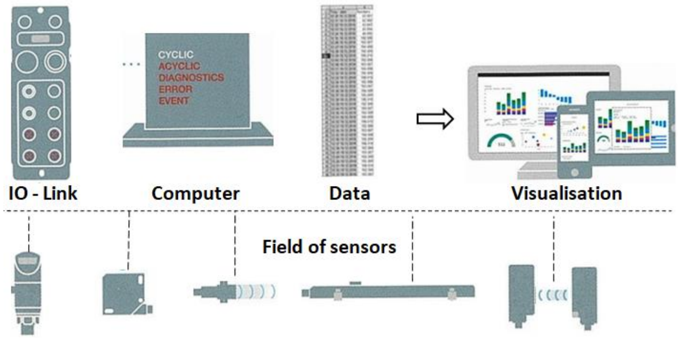

Fig.5. Scheme of intelligent predictive maintenance control.

In the application, which runs in augmented reality smart glasses, is the interaction between real and digital content performed through AR marker (tag). Workspace “Predictive maintenance of electric monorail system” was created and defined with unique selector and landmark in identical area to the physical location of the field of sensors. Once the workspace has been created, the individual digital tag is located in the space so that the information displayed in them complies with the requirements. For each tag, the source and path of the information (URL) to be displayed need to be defined, as well as the type of visualization. For better clarity, each description, picture, and status are assigned to each digital tag (Fig.6). The maintenance worker can visualize current and historical values from condition monitoring system in real time and just in place. Critical values from filed of sensors are highlighted and enable intelligent predictive maintenance control using augmented reality.

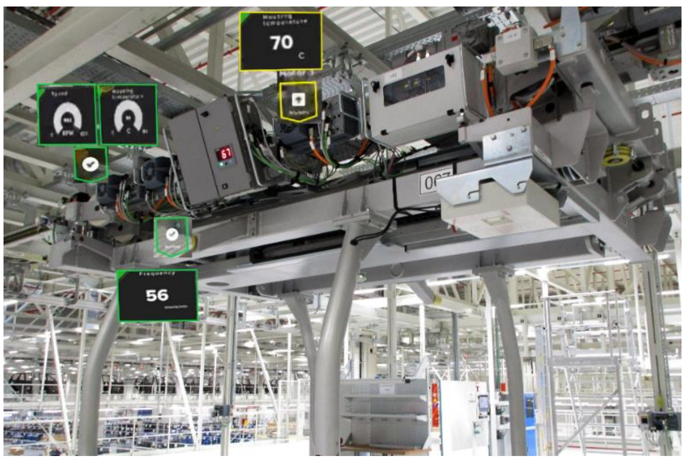

Fig.6. Realization of intelligent predictive maintenance control
of electric monorail system using augmented reality.

Conclusion

This paper presented an intelligent approach to predictive maintenance control using augmented reality smart glasses to support maintenance worker in automotive industry. Multiple functionalities involving the visualization of different types of production related data, instruction lists and one-point lessons have been implemented in this direction. From experimentally achieved results compared with preventive maintenance approach is evident significant improvement in following aspects:

- Increased quality of maintenance processes.
- Increased failure prediction.
- Reduction of unexpected production stops.
- Elimination of human factor.

Further research should focus on the integration of augmented reality systems to existing multilevel control structures and extension of the application functionalities (visualization without landmark, spare parts control and documentation).

The proposed methodology can be used for the predictive maintenance control of robotics, conveyors and other mechatronics systems in industry (automotive, aviation, biotechnology etc.)

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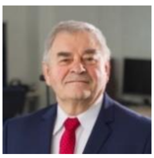

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