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[1] The Institute for Diagnostic Imaging Research, Windsor, Canada

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M. Wall [1]
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[1] International Committee for Non-Destructive Testing (ICNDT), Vienna, Austria

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B. Valeske [1]

[1] Chairman DGZfP NDE 4.0 / Fraunhofer IZFP, Saarbrücken, Germany

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[1] The American Society for Nondestructive Testing (ASNT), BOD, Research Council – Vice Chair, USA; [2] InspiringNext, Cromwell, USA

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[1] The Japanese Society for Non-destructive Inspection (JSNDI), Tokyo, Japan

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[1] University of Cassino and Southern Lazio, Cassino, Italy

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[1] Canadian Institute for NDE (CINDE), Hamilton, Canada

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[1] CEA List & COFREND, Paris-Saclay, France

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N. Meyendorf [1], N. Ida [2], R. Singh [3], J. Vrana [4]
[1] University of Dayton, Dayton, OH, USA; [2] The University of Akron, Akron, USA; [3] Plus4Pi LLC, Cromwell, USA; [4] Vrana GmbH, Rimsting, Germany

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[1] European Federation for NDT (EFNDT), Brussels, Belgium

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[1] UL LLC, Northbrook, USA

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GENERAL 1.1 – KEYNOTE

The NDE 4.0 – An Ecosystem Perspective

R. Singh[1], J. Vrana[2]
[1]InspiringNext, Cromwell, USA; [2]Vrana Gmbh, Rimsting, Germany

What you don't know can't hurt you does NOT apply to Digital Transformation. The current pandemic (Covid-19) is changing the value proposition of digital transformation from competitive advantage to a must do initiative. The hidden cost of not adopting Industry 4.0 is likely to be far greater than the visible cost of adopting it. In the inspection world, we call it NDE 4.0. When implemented, it promises value on all three dimensions - quality, cost, and schedule; to the stakeholders in the eco-system; from R&D to the leading edge of inspection. However, the very nature of the revolution requires that various stakeholders make concurrent efforts to adopt and master the application. For that, every constituent must see a value proposition from their vantage point. Must pursue the technology elements relevant to them in a manner that makes them compatible and synergistic with the value streams running across multiple directions. Value stream for inspection systems and the value stream for products in service, all anchored through a web of multiple digital threads that intersect at various points - the snapshot of inspection events captured by the individual digital twins. This eco-system perspective is like a Digital Weave Interlaced Digital Thread.

GENERAL 1.2

NDE 4.0: Redefining Traditional Inspector Roles

M. Bertovic[1], I. Virkkunen[2]
[1]BAM, Berlin, Germany; [2]Aalto University, Espoo, Finland

The successful shift to NDE 4.0 will not only require developing and embracing new technologies associated with the fourth industrial revolution or becoming an integral part of the overall Industry 4.0, but also developing and adopting new ways of working. It is undoubtful that people will remain in charge of the inspections. However, it is arguable if the current procedure-following level I-III paradigm can withstand the changes that come along NDE 4.0. With the increased autonomy and interconnectedness expected with NDT 4.0, the majority of traditional NDE tasks will no longer be needed. Instead, different skills, such as that of programming and adapting systems, as well as problem solving, will become vital for the inspections. Therefore, we suggest that a new paradigm is needed-one in which inspector roles and, thus, also the requirements will have to be reinvented. We expect the inspectors to be relieved from the tedious and error prone aspects of the current system and to take responsibility for increasingly complex automated systems and work in closer collaboration with other experts. Thus, we propose that the traditional inspector roles will be transformed into that of the system developer, caretaker and problem solver, each role requiring a specific set of skills and assuming different responsibilities. In this talk, we will present the new roles and discuss the challenges that may arise with them.

GENERAL 2.1

The SmartInspect System: NDE4.0 Modules for Human-Machine-Interaction and for Assistance in Manual Inspection

B. Valeske[1], S. Lugin[1], T. Schwender[1]
[1]Fraunhofer IZFP, Saarbrücken, Germany

Fraunhofer IZFP has developed a flexible NDE4.0 platform concept that consists of several complementary technology modules. Each of them demonstrates different features and innovations for future NDE4.0 devices and sensor systems as well as options for a beneficial integration in the IIoT. Generally speaking, the prototype system is our R&D approach to gain experience and advanced knowledge about the way of developing and implementing required features for future NDE4.0 sensor systems.
Together with partners from industry, the lab prototype is used for a proof of concept in specific applications of NDE4.0 sensor systems. The SmartInspect system contains interfaces for innovative interaction with users. SmartInspect is an intelligent assistance system that is designed especially to support and to help inexperienced operating personnel (human-machine-interaction HMI for NDE4.0) and can be used for UT, ET or micromagnetic multiparameter testing.
As we are generating only relevant data during data acquisition (e.g. by means of compressive sensing) the AR visualization can be streamed not only to AR displays but also to remote places via internet. NDE4.0 communication protocols (like OPC UA and DICONDE data format) can be supplied by the electronic modules and software of SmartInspect. These features offer completely new options for remote services and NDE4.0 workflows and for for training and education in NDE4.0.
Thus, advanced defect reconstruction algorithms are an essential element for real-time imaging of NDE results for flaw and defect visualization. For UT we combine compressed sensing with SAFT reconstruction (synthetic aperture focusing technique). The result is our real-time reconstruction algorithm progressive-SAFT that is for the first time also demonstrated for data acquisition during arbitrary manual scanning movement with our SmartInspect platform. For UT assistance in manual inspection, visualising the data in 2D (C-Scan) or even 3D (volumetric display, e.g., via AR display) eases the interpretation of the acquired inputs.

GENERAL 2.2

Reliability 4.0 – POD Evaluation: The Key Performance Indicator for NDT 4.0: The Essential Role of Reliability Evaluations in Modern Testing Environments

D. Kanzler[1]
[1]Applied Validation of NDT, Berlin, Germany

In the last five decades of reliability evaluation the majority of work has been done by research institutes for a small number of industrial branches (e.g. aerospace, nuclear power as well as the oil and gas sector). The Digitalization of NDT 4.0 will change the understanding of quality itself. Therefore, the connectivity within the IIoT (Industrial Internet of Things) demands objective Key Performance Indicators for the quality control and beyond. The capability and reliability evaluation of modern testing systems play an essential part in this discussion.
The audience are getting insight about the power of reliability evaluations within the NDT 4.0 framework and what has been accomplished (e.g. from ICNDT specialist group reliability of NDE and particular companies and institutes). It will be shown how a transformation into NDT 4.0 is possible using the Reliability Indicators in the individual sectors and within companies.
Standardization, tutorials and the clarification of the role of reliability in NDT 4.0, are currently the main purpose of the ICNDT specialist group. The presentation should address industrial partners; therefore, different case studies are shown, in which it can be seen that the revolution 4.0 is connected to the reliability evaluation.

GENERAL 3.1

Intelligent Measuring Transducers and Systems for Smart Factories. Structure, Standardization and Metrological Support

V. Syasko[1], R. Taimanov[2], K. Gogolinskiy[3], K. Sapozhnikova[2]
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[3]Saint-Petersburg Mining University, St. Petersburg, Russia

The basic principle "Digital end-to-end engineering across the entire value chain of both the product and the associated manufacturing system" implies the need for a similar design of NDT systems for physical and hardware-software interfacing of measuring transducers with cyber-physical systems (CPS) and distributed control systems while ensuring the unity of the principles of construction, operation, transmission and processing of measuring information, excluding the possibility of stopping production lines for setting, testing and verifying the NDT tools built into the technological process.

The report discusses the basic principles of constructing measuring instruments for smart factories, consisting of an intelligent primary measuring transducer, software and hardware interfaced to the CPS, a standardized wireless communication channel, a virtual secondary measuring transducer built using cloud technologies, digital twins "measuring transducer - object of control included in the distributed control system.

Terms and definitions in the field of standardization and uniformity of measurements of intelligent adaptive measuring transducers, based on the principles of direct metrological and diagnostic self-control and information redundancy, providing:

- automatic correction of the error resulting from the influence of influencing quantities and / or aging of the components;
- metrological self-healing in the event of a single defect;
- self-study;
- remote verification.

The investigated principles of construction and standardization of intelligent measuring transducers, as well as multi-parameter spatially distributed systems NDT and CM built on their basis, will create the basis for a significant increase in the values of intertesting intervals or exclude this concept and will provide the required reliability of NDT and CM results in the conditions of existing and future smart factories , subject to the development of principles for validation and verification of digital models, as well as a number of other tasks of metrological support.

GENERAL 3.2

Role of Diversity and Inclusion in NDE 4.0

C. Bull[1]
[1]Past President BINDT, United Kingdom

What is diversity and inclusion? What are the benefits for our community and for all those working in NDE and NDT, condition monitoring, structural health monitoring and all the associated science and technologies? How can diversity and inclusion strategies influence the outcomes of NDE 4.0 research and development and support the implementation of technologies in industry? What does the future hold?
Caroline Bull is Past President and Trustee of the British Institute of Non-Destructive Testing and works for a UK Defence Company. With a passion to champion D&I in all she does, Caroline will address some of the matters that will affect our community as we move forward with the adoption of NDE 4.0 technologies.

TECHNICAL BASICS 1.1 – KEYNOTE

Digitalization for Industries – Era of Augmented Intelligence

R. Bucksch[1]
[1]IBM Deutschland GmbH, Frankfurt, Germany

How can Digitalization help to provide actionable insights from structured and unstructured data? Most scalable IIoT solutions are based on a platform on which data is collected. For this purpose, production level data - if necessary with an intermediate step via edge devices - must be transferred to a cloud platform and collected centrally. To make them read- and understandable, the data is put into an integrated context with the help of reporting functions. This makes it possible to establish dependencies between the data, the various production areas, product quality and machine availability. In the next step, the application of analytical functions helps to gain insights, for example to achieve improvements in product quality.
IBM complements these solutions with two elements: From predictive maintenance you move to prescriptive maintenance, i.e. it is not only said what happens, but what is the best action. The second element is the analysis of unstructured data. Unstructured data can take the form of images, manuals, machine repair tickets, flyers, Post-its, etc. The analysis system is taught-in, i.e. initially filled with structured and unstructured data. Depending on the quality and quantity of the data, the initialization takes different lengths of time. The result is faster and more flexible quality assurance and production optimization.
In a nutshell you could consider the latter as a journey from data collection to big data, transfer to smart data, upon which new business models and new revenue streams could be established.
This lecture presents various application scenarios that are also suitable for small and medium-sized enterprises and different batch sizes and complexities. The range of digitization of industry (Industry 4.0) and current developments in the field of artificial intelligence is stretched. Furthermore, a context is given from current to future capabilities in the area of hardware and software in IT.

TECHNICAL BASICS 1.2

The Core of the Fourth Revolutions: Industrial Internet of Things and Digital Twin

J. Vrana[1]
[1]Vrana GmbH, Rimsting, Germany

Like with the previous revolutions the goal of the fourth revolution is to make manufacturing, design, logistics, maintenance, and other related fields faster, more efficient, and more customer-centric. This holds both for classical industries, for civil engineering, and for NDE and goes along with new business opportunities and models.
Core components to enable those fourth revolutions are semantic interoperability, converting data into information, the Industrial Internet of Things (IIoT) offering the possibility for every device, asset, or thing to communicate with each other using standard open interfaces, and the digital twin converting all the available information into knowledge and closing the physical-virtual-physical loop.
For NDE this concept can be used #1 to design, improve, and tailor the inspection system hard- and software and #2 to choose and shape to best inspection solution for the customer or to enhance the inspection performance. Enabling better quality, speed, and cost at the same time.
On a broader view, the integration of NDE into IIOT and Digital Twin is the chance for the NDE industry for the overdue change from a cost center to a value center. In most cases, data gathered by NDE is used for a quality assurance assessment resulting in a binary decision. But the information content of NDE goes way deeper and is of major interest for multiple additional different groups: engineering and management. Some of those groups might currently not be aware of the benefits of NDE data and the NDE industry makes the access unnecessarily difficult by proprietary interfaces and data formats. Both those challenges need to be taken on now by the NDE industry. The big IT players are not waiting and, if not available on the market, they will develop and offer additional data sources including ultrasonics, X-ray, or eddy current.

TECHNICAL BASICS 2.1

A Concept of Digital Platform for NDE 4.0

M. Ochiai[1], S. Yamamoto[1]
[1]Toshiba Energy Systems and Solutions Corporation, Yokohama, Japan

Toshiba is a plant manufacturer of energy and social infrastructure systems, as well as a service vendor involved in the operation and maintenance of operating plants. Regarding non-destructive testing (NDT), we not only provide inspection services for manufacturing and maintenance, but also have long been developing and applying lots of special inspection systems in-house.
Recently, we are focusing on digitalization of NDT data and also increasing values by linking and utilizing data using our digital platform. We consider NDT digitalization in 3 steps: I. Fundamental digitization, II. Vertical integration of NDT data, and III. Horizontal integration to create new solutions. In step.I, not only digitization of flaw detection data, but also system information, inspector information, and document digitization are included. These are integrated with advanced digital technologies such as local-5G communication and AR / VR. In step.II, various NDT data are linked and utilized. By sharing NDT data across inspectors, NDT systems, production lines, test subjects via digital platform, for example, it should enhance the performances of AI and deep learning and improve the quality of NDT results. In step.III, data is linked through the supply chain, not limited to NDT. By combining NDT data with a wide variety of data such as pre-manufacturing processes of test subjects or operation history after in-service, new solutions for asset management such as lifetime prediction, operation planning, inspection / renewal planning, etc. will be created.
In this presentation, we will introduce some practical examples of Toshiba's activities on this fields and propose a concept for future international cooperation and discussion.

TECHNICAL BASICS 2.2

Explainable Artificial Intelligence for the NDE 4.0

A. Osman[1], Z. Wei[2]
[1]Fraunhofer IZFP, Saarbrücken, Germany
[2]University of Applied Sciences, htw saar, Saarbrücken, Germany

As AI Deep Learning (DL) methods have achieved super human-level performance in many tasks, NDE should naturally profit from this advance. However, the implementation of DL in NDE is decelerated by the lack of transparency and explainability of the DL models. While the traditional AI systems are easily interpretable, the last years have witnessed the rise of opaque DL Networks. Opacity is the opposite of transparency. By making a DL-Model transparent and explainable, we aim at reducing its opacity and understanding the mechanism by which the model acts. The success and high capability of DL-models for approximating any function stems from their huge parameters space, complex architecture, activation functions, efficient initialization and optimization algorithms. It is safe to say that highly accurate DL-models are increasingly opaque which will increase the challenge to explain them. This has been an active research topic in the last 6 years. Nowadays there are different methods trying to explain some deep models regarding different aspects. One of the most popular methods is saliency map method. It generates a saliency map in the input data space based on their contribution to the models prediction. This saliency map can then be used to assess if the model has used the correct features or not. Another method is to generate an artificial input example that maximize a certain output unit, in this way an insight of what the deep model has really learned can be obtained. Within this contribution, we will tackle the advance in the explainable AI scene and present applications of it for NDE examples. For the NDE society, we want to move toward the concept of Responsible Artificial Intelligence, namely, a methodology for the large-scale application of AI methods in NDE with model explainability, reliability and generalization (especially regarding varying materials anatomy) at its core.

TECHNICAL BASICS 3.1

The Next Paradigm in NDE 4.0 - Computation Assisted Automation of NDE Decision Making

K. Balasubramaniam[1]
[1]Indian Institute of Technology Madras, Center for NDE, Chennai, India

Asset Integrity and Process Monitoring technologies have a logical impact on operational costs. Efficiencies realized by effectively managing labour, inventory and other support services directly impact the bottom line by helping to control costs. More timely and precise user intervention can improve productivity, reduce materials use and decrease the cost of doing business.
The emergence of NDE 4.0, that was an outcome of the emergence of industry 4.0 as a precursor, proposes to change the way we do NDE over the next 3-4 years. Here, in NDE 4.0 several technologies including robotic inspection, big data analytics, AI based decision making are under development. Here, the decisions are made based on rules that were derived using experiences and calculations that were done off-line.
The future will be driven by the rapid computation driven NDE 4.0 paradigm that will leverage the technologies already developed in NDE 4.0 but will be implicitly based on complex calculations performed in real time in a ubiquitous and pervasive manner. The following figure shows the transition of the NDE x.0 technological metamorphosis over the past 4 decades.
In the way forward, the deployment of intense and extremely rapid computational models along with near-real-time computation will bring forth the computationally driven NDE 4.0. Here, the computation will assume the form of ubiquitous computing that will lead to decisions that are driven by real time evaluation of the cause-effect scenarios as the inspection is taking place. This includes replacement of the AI Trained engines with simulation based Trained Engines and decision and interventions based on the decisions driven by AI trained computational engines.

TECHNICAL BASICS 3.2

Ultrasonic Nonlinear Imaging for Nondestructive Testing Integrity Engineering within Industry 4.0: Signal, Image and Data Analysis for Monitoring Ageing

S. Dos Santos[1]
[1]INSA Centre Val de Loire, U1253 iBrain "Imaging and Brain", Blois, France

The growing interest for nondestructive testing (NDT) methods based on nonlinear acoustic effects has increased continuously since the first studies in the early 1980s. It has been shown that micro-inhomogeneities such as cracks lead to an anomalously high level of nonlinearity, monitoring ageing of the material. In particular, nonlinear ultrasonic (US) has become important due to the increase of higher sensitivity of the instrumentation and its associate signal processing. Instrumentation needs basics from applied physics and will concern all disciplines of engineering, including applied mathematics, computer science, modern automation and robotics for Industry 4.0. The nonlinearity of materials results in nonlinear effects, which arise from defects in the materials, usually considered as small signals or noise.
The main perspective of this keynote is to present a review of nonlinear US automated systems for characterizations of materials and structures within modern NDE 4.0 based industries. The systemic NDE optimal design should be at the skeleton of NDE4.0, the key component of the smart factory described in Industry 4.0 concepts. Regardless of how the concept of system is defined or specified by the different paradigms and approaches, the notion of complexity of ageing or integrity is based on the idea that information coming from such complex systems could be accurately known (determinist) or could contain uncertainty and noisy aspects (stochasticity). The degree of complexity could be estimated as the proportion of the stochastic part with respect to the deterministic one. This stochastic proportion should measure the multiscale property of any system, and constitutes the skeleton of any artificial intelligence associated to NDE4.0 [1]

[1] Dos Santos, S. (2020). Advanced Ground Truth Multimodal Imaging Using Time Reversal (TR) Based Nonlinear Elastic Wave Spectroscopy (NEWS): Medical Imaging Trends Versus Non-destructive Testing Applications. In Recent Advances in Mathematics and Technology. Birkhäuser, Cham. https://link.springer.com/chapter/10.1007/978-3-030-35202-8_4

APPLICATIONS 1.1 – KEYNOTE

Digital Inspection – Technology & Business Model Transformations in NDT

P. Shanmugam[1]
[1]Frost & Sullivan, Toronto, Canada

Industry 4.0 trends have a strong impact on NDT market and is transforming the role of NDT inspection in the larger scheme of production and maintenance. This presentation would highlight some of the current transformations and future roadmap of NDT in terms both technology and business models.

APPLICATIONS 1.2

Generic Models for the Automated Evaluation of Non-Destructive Test Situations

C. Grosse[1], M. Mosch[1]
[1]Technical University of Munich, Chair of Non-Destructive Testing, Germany

Quality assurance using non-destructive testing (NDT) methods is of increasing importance for the manufacturing of constructions and components in many industries including automotive, aeronautic and energy systems. While the use of computer-aided design techniques is nowadays self-evident and such techniques are applied quite early in the production process, this is not equally true for NDT techniques, where the testability remains often unconsidered. As a result, later inspection costs are high or a redesign can even be inevitable.
A generic model approach is able in the early design process to address this issue by highlighting the requirements of NDT for certain parts and geometries allowing for an optimization. This is certainly essential for highly optimized structures and specific quality assurance conditions as they are for example typical for aeronautic structures.
In close cooperation with the industry, such a generic model approach was developed in two parts. The static part describes the test situation while the functional part evaluates the interaction of the static elements. For a typical component with different geometrical challenges, the approach is demonstrated and the testability determined within the various aspects of NDT. Design considerations for a carbon fiber-reinforced plastic part are presented as well to demonstrate the applicability concerning state-of-the-art lightweight constructions. As final outcome, further improvements of the generic model technique including automated evaluations are described. Based on this ideas a software tool is presented that can be applied in the construction process.

APPLICATIONS 2.1

NDE 4.0 in Civil Engineering – Obstacles and Opportunities

E. Niederleithinger[1]
[1]BAM, Berlin, Germany

Civil engineering industry is one of the most important industry sectors in the world-wide economy. It contributes significantly to the gross economic product and general employment. Even more important, it provides many of the basic needs of the society (e. g. housing, infrastructure, protection from natural hazards).
The concept of Industry 4.0 or Smart Production has not yet made significant progress in the civil engineering industry. The design, build and operate processes are still widely dominated by the exchange of printed documents and drawings. Most objects (buildings and other constructions) are unique, and a large part of the production still requires a large amount of manual labor. As-built documentation and quality assurance are often neglected. Civil engineering is among the industries sectors with the lowest level of digitalization and the lowest gain in productivity.
However, this is going to change. In the past decade, several drivers have challenged the ways clients, contractors, and authorities currently operate. These drivers include but are not limited to an increasing demand for serialization and automatization, the mandatory introduction of Building Information Modeling (BIM) in public procurement, the availability of construction equipment with sensors and digital interfaces or emerging automated construction technologies such as 3D-printing.
NDE (referred to as NDT-CE in this sector), after a rapid technological development in the last two decades, plays an increasing role in quality assurance, condition assessment and monitoring of structures. However, with very few exceptions, applications are mostly non-standardized and performed only at selected sites. To change this, the NDT-CE community including manufacturers, service providers, clients and the scientific community must work consistently on open data formats, interfaces to BIM, standardization and validated ways for a quantitative use of the results in the assessment of constructions.

APPLICATIONS 2.2

Practice of NDE 4.0 Concept in Cases of In-service Railway Wheelset Inspection

X. Gao[1], J. Peng[1], Y. Zhang[1], C. Peng[1]
[1]Non-destructive Testing Center, Southwest Jiaotong University, Chengdu, China

The running parts quality is one of the fundamental issues concerning the safety of high-speed railway. With the strategic transition from planning-based maintenance to condition-based maintenance for crucial parts of the trains, a five-level comprehensive inspection system was established to increase inspection functions and detection areas. Based on the concept of industry 4.0 and railway 4.0, the prototypes of NDE 4.0 in railway were introduced to achieve full-life-cycle management for railway assets. In this paper, focusing on in-service railway wheelset inspection, two practical examples for application of NDE 4.0 are discussed. Wheelset lifetime forecasting model and algorithm are analyzed according to wheelset daily inspection data, and suggestions for the maintenance schedules are given by the digital twin model. Similarly, the level of abrasion of the brake pad is studied, and balanced maintenance plans are conducted. With the help of data mining and artificial intelligence, trend analysis and critical threshold evaluation of failures become possible. In this way, traditional NDT methods are empowered to meet both the safety and economic needs of the railway industry.

APPLICATIONS 3.1

Perspectives of NDE 4.0 Applications in Automotive Manufacturing

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The automotive manufacturing industry stands to greatly benefit from Industry 4.0, but its implementation presents many challenges that must be overcome. Industry 4.0 requires NDE 4.0, which often requires the integration of various innovative solutions, including implementation of artificial intelligence (AI) into the process of NDE data interpretation. In this talk, I will discuss the benefits and challenges of Industry/NDE 4.0 in the context of automotive manufacturing, including signal/image processing and AI, and elaborate on the roles of AI in Industry/NDE 4.0.
I will also present an intriguing case study which highlights the considerations and challenges of transforming a pre-existing NDE system for an automotive application real-time integrated resistance spot weld analysis for NDE 4.0, through the integration of AI and, in particular, deep learning algorithms. This case study involves discussion of the original automated NDE system, the development of a deep learning component for NDE data interpretation, the considerations for the development of a feedback system including further development of an adaptive control algorithm for resistance spot welding. These elements (automated NDE data acquisition and big data storage, fast AI-based interpretation, super high speed feedback, and adaptive control) are essential to NDE 4.0, and the concept of zero-defect manufacturing in the automotive industry. Finally, we will discuss further horizons of this technology development and what kind of impact we expect to await here in the near future.

APPLICATIONS 3.2

NDE 4.0 for In-Service Inspection, Monitoring and Integrity Management in the Energy Sector (including HOIS Initiatives)

M. Wall[1]
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Digital transformation is all around us and forms an increasing part of our daily lives. For inspection and monitoring, the emerging technologies behind this revolution in automation and use of data (including AI/machine learning, digital twins, cyber-physical systems (CPS), autonomy, cloud computing, information flow and transparency, big data processes, the internet of things (iOT)) and augmented reality) are collectively referred to as NDE 4.0. Inspection and monitoring data are increasingly acquired using robotic or automated systems and sensor networks that gather large amounts of data in a digital framework. This is true of advanced NDE methods used in aerospace or more routine automated inspections like MFL floor scanning of oil storage tanks. Data acquired in this way is amenable to NDE 4.0 solutions and display in digital twins.
The paper will give an overview of the use of NDE 4.0 technologies in the energy sector for in-service inspection, monitoring and integrity management including initiatives within the HOIS JIP and forum (www.hois.co.uk) including a core digitalisation and NDE 4.0 programme; landscape study, a forward road map the HOIS Digital and NDE 4.0 Agenda. Examples include guidance on data information flow; cloud data storage for acquisition, storage, processing, and reporting of NDE inspections; use of photogrammetry and optical methods and bespoke software to build plant level digital twins (DTs) offshore and subsea; mini-DTs for storage tanks and process vessels; guidance for use of drones and AUVs for remote visual inspection (RVI, CVI), and robot crawlers for remote internal inspection (RII) of pressure vessels.
Early uptake is most likely for new NDE technologies with large NDE data requirements (robotics, phased arrays); for improved visibility and integrity analysis of data via mini-DTs; or for time consuming NDE activities such as analysis of more complex NDE data sets. FMC, PAUT, TOFD).

NDT SOCIETIES 1.1 – KEYNOTE

ICNDT Actions on NDE 4.0

S.K. Babu[1], M. Farley[2]
[1]Chairman of ICNDT, Vienna, Austria; [2]Chairman of ICNDT, Vienna, Austria

ICNDT has been supporting the development and implementation of the science and technologies of Nondestructive Testing for more than 60 years.
Nowadays, at the beginning of the 2020s the not-for-profit organization, registered in Vienna, which is the focal point of NDT Societies the world over must address both the NDT practiced now and also the opportunities and challenges of the next industrial revolution, NDE 4.0, as well as the challenges of the Covid 19 era and new ways of communicating.
Ten years ago, in its Strategic Planning ICNDT recognized the importance of advanced digital imaging and ran a workshop on the topic at the 18th WCNDT.
In 2016, at the 19th WCNDT, the membership agreed to set up a series of Specialist International Groups in topic areas of importance where the membership considered international cooperation should be encouraged in between World Conferences. NDE 4.0 was one of these topic areas and subsequently the group was initiated with Dr Johannes Vrana as its Chair. Sessions and workshops were planned by the Group at the 20th WCNDT which of course was postponed. International cooperation continued and this led to an agreement to merge the SIG with a group known as the NDE 4.0 Ambassadors, started in the USA. The merged group will continue as an ICNDT SIG and the Ambassadors are invited to join.
ICNDT will continue to encourage the development and application of the technologies which contribute to NDE 4.0 and, even more important, will seek to work with users of NDT in all branches of industry, who wish to properly integrate NDT into the full lifecycle of their products and equipment.

NDT SOCIETIES 1.2

A Global NDE 4.0 Roadmap – From the Journey to its Creation towards a Pathway for its Sustainability and Evolution

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Regardless of its local name, fahrplans, hoja de ruta or feuille de route, Roadmaps through time have been instru-mental for guiding and thrusting sociocultural, economic, technological and even political changes around the world.
When in recent months a diverse community of NDE 4.0 stakeholders, dispersed over continents and industries, began to interact and bring together a series of common challenges and collaboration initiatives, two questions materialized from those early interactions: "Does the integration of a global NDE 4.0 roadmap is feasible?" and "Does creating such global roadmap truly matters?".
This presentation, and its associated article, aims to provide an answer to both questions by succinctly portraying:
1) The journey to a create a Global NDE 4.0 Roadmap, understanding it as a milestone initiative, through a process that comprised from the mapping of the NDE 4.0 national ecosystems to the definition of a strategic path to reinforcing a Global NDE 4.0 Ecosystem.
2) The pathway for its sustainability and evolution through the integration of specific reinforcing mechanisms and processes since its early design.
By merging strategy and innovation, our purpose is also to contribute with the global NDE community by provid-ing valuable practical insights related with:
1) Using and adapting the global NDE 4.0 roadmap to specific needs in order to create specialized roadmaps by industry or geographic region, that are both feasible and relevant.
2) Presenting a strategic sustainability perspective towards the future that may serve as guidance and inspira-tion to keep those specialized roadmaps relevant and useful
3) Integrating the human perspective into NDE 4.0 through professional and personal development paths and certifications, and finally
4) Outlining an agenda of future research aligned with the purpose of NDE 4.0 of contributing to creating a safer and more sustainable word.

NDT SOCIETIES 1.3

Progress Towards NDE 4.0 from BINDT Perspective

N. Brierley[1], R. Smith[2]
[1]diondo, Hattingen, Germany; [2]University of Bristol, United Kingdom

The transition to NDE 4.0 is recognised to offer numerous opportunities, whilst also presenting several challenges. The BINDT group on the subject has been set up to help guide the UK NDE and condition monitoring communities important especially given the cross-industry and cross-subject-area coordination required to enable significant interoperability, for example. The group has been gathering significant momentum, with a rising membership across a wide range of industries, organisations etc. The group has been working on a roadmap to highlight developments, needed for enabling specific envisaged benefits of NDE 4.0, spanning technical and non-technical considerations. Amongst the former, the means of qualifying advanced algorithms is a key challenge, whilst amongst the latter, enabling regulatory acceptance of novel inspection approaches is a potential future bottleneck. Both should be tackled early on, to prevent overall progress being delayed.
This presentation will summarise the efforts of the group, and highlight some of the relevant recent and ongoing work in the UK.

NDT SOCIETIES 1.4

DGZfP Expert Committee "NDE 4.0": Goals, Activities and Fields of Work

B. Valeske[1]
[1]Chairman DGZfP NDE 4.0 / Fraunhofer IZFP, Saarbrücken, Germany

The expert committee NDE4.0 of the German Society for Nondestructive Testing was founded in June 2017. At present, the committee has about 60 persons in its core groups who are actively working in various fields of activities and in total some 30 guests and advisory members. Since then, we have clustered our fields of work in Germany in 3 sub-groups (SG1 – SG3):
(SG1) Interfaces and Data (NDE4.0 ecosystems and IIoT)
(SG2) Human-Machine-Interaction (new workflows / legal, psychological, social aspects / acceptance)
(SG3) Education for NDE4.0 (future qualification elements for NDE4.0, digitalization for NDE training)
Furthermore, we have established 5 working groups which are covering the following fields of competence (WG1 – WG5):
(WG1): OPC-UA and companian specification
(WG2): DICONDE data format
(WG3): Applied artificial intelligence for NDE 4.0 (trusted and approved AI in NDE4.0)
(WG4): NDE for additive manufacturing
(WG5): NDE4.0 in building and construction industry / infrastructure
A short overview on the goals and activities of the different groups will be presented as well as some results and experiences made during the first 4 years of the NDE4.0 committee. In addition, the focus in Germany in the field of NDE4.0 will be discussed, which is closely linked to the (r)evolution and development of industry 4.0 and the internet of things as well as on strategies for the fundamental change in the role and mission of future NDE and for the transformation toward NDE4.0 in the digital age.

NDT SOCIETIES 2.1

ASNT Initiative on NDE 4.0

A. Poudel[1], R. Singh[2]
[1]The American Society for Nondestructive Testing (ASNT), BOD, Research Council – Vice Chair, USA
[2]InspiringNext, Hartford, CT, USA

ASNT started its NDE 4.0 journey during the Spring 2018 Research Symposium. Over the last three years, we have taken a collaborative approach along with our DGZfP partners in conducting workshops, NDE 4.0 technical tracks at our conferences, kicked off an ASNT committee, and started looking at guidance for a global eco-system roadmap.
We as a group are also trying to understand what each country is doing to push innovative NDE technologies for a safer world. We are trying to understand the bigger picture on some of these focused topics:

- What NDE technologies can be of real value in the emerging scenario?
- What should we do as a society to adopt and what can we live without Thinking new normal?
- What direction industries globally can explore?

This presentation will dwell on these efforts and share some unresolved concerns around regulation, validation, and certification; highlighting the need for more collaboration and creative approaches to transformation.

NDT SOCIETIES 2.2

Recent Activities Related to NDE4.0 in JSNDI

M. Ochiai[1]
[1]The Japanese Society for Non-destructive Inspection (JSNDI), Tokyo, Japan

The Japanese Society for Non-Destructive Inspection (JSNDI) is an organization where Japanese industry, academia and government meet together to discuss all matters related to Non-Destructive Testing (NDT). The scope of JSNDI covers academic activities related to NDT, management and establishment of ISO and national standards, and certification of NDT personnel. It also includes education and training of NDT personnel, editing and publication of NDT materials. JSNDI is also the secretariat of ISO TC135 and Asia-Pacific Federation of NDT (APFNDT).
In Japan, digitization of NDT has long been promoted, whether it was called NDE 4.0 or not. Currently, most NDT data is somehow digitized, analyzed and stored. Using these big data, many characteristic and latest methods utilizing such as AI and machine learning are also being studied.
These technical activities have been carried out by individual research organizations and companies. Due to the growing interest in NDE4.0 worldwide, JSNDI has established a planning committee for engineers and researchers to gather and discuss NDE4.0 in Japan.
NDE is originally a data-oriented technology and has a high affinity with digitalization. One of the essence of digitalization is the sharing and mutual-use of data. For this purpose, multi companies, industries and international cooperation are important. By developing NDE4.0 from the viewpoint of optimization of supply chain and Product Life Management (PLM), we believe NDE4.0 has a potential to transform NDT to more valuable process and leads revolutionary industrial solutions.

NDT SOCIETIES 2.3

The Next Steps of AIPND for NDE4.0

L. Ferrigno[1], A. Tamburrino[1]
[1]University of Cassino and Southern Lazio, Cassino, Italy

The Italian Association for Non-Destructive Evaluation (AIPND) is organizing its structure to respond to novel national, European and international challenges related to NDE4.0.
Typically, AIPND organizes its activity through scientific working groups and in this case it is also organizing a working group able to create synergies between scientific and technical entities with some goals to reach:
a) To collect the needs of the scientific and industrial world with respect to issues and needs of NDE 4.0;
b) to organize technical tables that bring together the technical and scientific worlds with respect to the main themes of NDE 4.0;
c) To organize seminars, workshops to disseminate content on specific themes of interest as metrology, artificial intelligence, standardization, etc.
d) to encourage the participation to national and international calls about research and developments of solutions for NDE4.0.
Next steps of AIPND will be:
i) formalize the working group, define the president of the working group and create the thematic subgroups;
ii) to invite companies and associates to participate in the working group's activities;
iii) to create a questionnaire to identify industrial criticalities at a national level about NDE 4.0;
iv) define the ways and the strategies to involve companies.

NDT SOCIETIES 2.4

NDE 4.0 – Updates on Current and Future Activities within Canada

D. Andrews[1]
[1]Canadian Institute for NDE (CINDE), Hamilton, Canada

The use and adoption of NDE 4.0 has been accelerated due to the current unprecedented global challenges that we are facing. This presentation will provide updates on the current and future activities of NDE 4.0 within Canada.

A committee of specialists in the area of NDE 4.0 has been created and continues to grow - helping to inform some of the actions moving forward at a national and international level relating to NDE 4.0 and its use within the non-destructive testing industry. The committee, co-chaired by Dr. Roman Maev (University of Windsor) and Don Andrews (Canadian Institute for NDE), aims to bring together various sections of industry to ensure that a path forward takes a number of perspectives (academic, industry, and standards) into account.

A preliminary road map will be provided that will demonstrate our plan moving forward with input provided by industry as well as the Natural Resources Canada National NDT Certification Body will be provided.

NDT SOCIETIES 3.1

Scientific and Technical Activity at the French NDT Society COFREND in Connexion with NDE 4.0

P. Calmon[1]
[1]CEA List & COFREND, Paris-Saclay, France

The French NDT society, COFREND, gathers scientific experts from academy and industry within its Scientific and Technical hub whose mission is to favor scientific exchanges and promote technical innovation in the field of NDE. To fulfill this objective COFREND organizes, scientific events, such as the Doctorial COFREND days which allow young researchers to share their current works and latest results, with industry, or symposia dedicated to specific thematics. In parallel to the animation of these exchanges, the Scientific Committee of COFREND impulses working groups focused on various topics of interest for the industrials, taking into account the needs of specific skills and training as well as of the deployment of adapted certification. In this presentation, we will give an overview of this scientific activity carried out in these COFREND WGs and we will emphasize on the works the most connected to NDE4.0: Structural Health Monitoring, Simulation, NDE and additive manufacturing, AI for NDE etc.

NDT SOCIETIES 3.2

The NDE 4.0 Handbook

N. Meyendorf[1], N. Ida[2], R. Singh[3], J. Vrana[4]
[1]University of Dayton, Dayton, OH, USA; [2]The University of Akron, Akron, USA;
[3]Plus4Pi LLC, Cromwell, USA; [4]Vrana GmbH, Rimsting, Germany

NDE 4.0 will significantly change the way we will operate NDE in the future. Modern manufacturing techniques producing complex individual components tailored to the needs of individual customers will require that aspects of NDE reliability and the effect of the human factor have to be reconsidered. New tools like the internet of things, big data, digital twins, and artificial intelligence for instance will give now opportunities to perform NDE in the lab, in the field and also remotely. This will also raise new question how to integrate and execute NDE in production in a cyber-physical environment and how to process, analyze and protect NDE data. This will challenge the NDE stuff. The goal of the first Handbook of NDE 4.0 is to document what is being done to address these issues and to anticipate the needs of the NDE community in this exciting and challenging new frontier. The Handbook will describe the new trends and techniques and will be a guide to application of NDE in modern industrial environments. This will also include NDE techniques and NDE data processing that have high potential for cyber physical controlled production and discuss these applications for different industries.
Contributions to this work will be published first online immediately after review, followed by a printed book. First chapters of this book will be available during the conference. When complete by the mid-2021, the handbook will have over 1500+ pages of content, structured under 50+ peer reviewed chapters, from nearly 100 expert contributors from 10 countries. The electronic version will remain live to stay current with times on this rapidly evolving topic. An overview what can be expected in the next future will be given.

NDT SOCIETIES 3.3

Robotics serving NDE 4.0 – the RIMA Project

P. Trampus[1]
[1]European Federation for NDT, Brussels, Belgium

Robotics for Inspection and Maintenance (RIMA) is a 4-year project aiming to reinforce the connection between Europes rich technological offer and the market needs and high potential applications in the field of Inspection and Maintenance (I&M). Further goals are to provide education and training on I&M robotics as well as to connect the value chain (research, technology companies, service providers, end users and investors) to have an impact for accelerating economic growth in this field and extending EUs leadership in this sector. RIMA concentrates on I&M in a large area spanning across multiple sectors such as energy, nuclear, oil and gas, water supply, transport and civil engineering infrastructure. There is massive potential for robotic applications, to increase productivity and improve safety.

To achieve this, RIMA formed a network of 13 Digital Innovation Hubs (DIHs) on robotics offering services such as technology scouting (including digitalization, artificial intelligence, machine learning etc.), feasibility studies, project plans, identification of technological trends and innovation sprints. The network is enriched with industrial organizations and associations like the European Federation for Non-Destructive Testing (EFNDT) that have the links and means to promote the innovations coming from the DIHs to their regional stakeholders. DIH typical clients are the Small and Medium Enterprises (SMEs) who have a problem related to deployment of robotics in their industrial processes. Stakeholders can be the members of the European national NDT societies facing NDE or overall in-service inspection challenges, and thus can be beneficiaries of RIMA, namely 50% of project budget is distributed to SMEs to run experiments within the framework of two open calls.

The presentation intends to describe the RIMA project, the working process of the DIH network and the NDE related success stories of the first open call.

NDT SOCIETIES 3.4

Current Topics in Remote Inspection

M. Dotlich[1]
[1]UL LLC, Northbrook, USA

Both digitalization and the global pandemic have increased the need and availability for remote inspections. In this talk, we will discuss a number of current topics in Remote Inspection. The main topic areas will be:
The definition and types of remote inspection such as digital inspection, video inspection, augmented inspection, and remote visual inspection.
The ways remote inspection can be conducted such as video conferencing, document sharing, robotic cameras, as well as, the technologies used for remote inspection.
The assessment process for when remote inspection can be done including risk to health and safety, accessibility of the environment, and availability of qualified personnel.
The technical requirements to ensure that the remote inspection will be successful including data protection, reliable wifi or cellular, qualified personnel, smart or augmented tools, appropriate software, training needs.
The benefits of remote inspection including speed of delivery, cost benefits and disadvantages, and positive quality effects as well as potential downsides.

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