Using DICONDE for NDT Data Exchange

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Abstract

The processing of multiple data sets from different NDT vendors and systems can be challenging. Accessing the data requires dealing with different and often proprietary data formats. In addition to that the correct spatial alignment requires knowledge and information about the acquisition system and must consider different approaches for markers and reference coordinate systems. The key features of NDE 4.0 and digital twin concepts are storage and interoperability with standard data formats. In this example data from thermography, manual ultrasonic testing and immersion ultrasonic testing are considered. For established devices multiple tools exist for the conversion of data into image-based formats. However, besides the lack of spatial alignment there is a need to access the raw data for further processing. In medical and CT-like applications the DICOM format has become a widely used exchange format. Its derivative DICONDE transfers this into the field of NDT. This study demonstrates the use of this format for data processing from multiple NDT methods and addresses issues related to interoperability and the integration of less structured data from inspections.

KEYWORDS: interoperability; data; ultrasonic; exchange; processing

1. Introduction

NDT methods such as Visual Testing (VT), Ultrasonic Testing (UT), Computed Tomography (CT), Radiographic Testing (RT), Thermography (TT) and Eddy-current Testing (ET) are used as the initial step to assess and evaluate components [1]. Individual NDT methods give information about the component at various levels of resolution and sensitivity. Similarly, diversity and complexities of components pose challenges for the accurate assessment of structures and components. The combination of NDT methods can enhance the assessment of structures [2]. In multi-modal NDT data fusion, the combined/fused image provides an enhanced information of the structure compared to the single images and thus subsequent defect classification and assessment of the structure. Fusion and exchange of data from multiple NDT methods can be challenging and requires standard data formats. Open data formats and interfaces are key to the data exchange between different devices in the context of Industry 4.0 [3]. NDT hardware and software developers often use and implement custom data formats and interfaces. This reduces compatibility and makes systems less adaptable and interchangeable. Even with the

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metadata for different NDE methods, non-uniform data formats make it difficult to benefit from existing data sources for applying different data processing algorithms [4]. The Digital Imaging and Communication for Non-destructive Evaluation format (DICONDE) is regarded as a unified data format that can meet the requirements of the NDE 4.0 concept [5]. DICONDE is based on DICOM, a standard from medical imaging for the transfer, storage, exchange and archiving of medical-related information [6].

The purpose of this paper is to study the DICONDE data format standard for data exchange. A depiction of available tools/frameworks for conversion of raw and proprietary files from ultrasonic testing of components will be considered. Also, the representation of data from individual sensors in the DICONDE format, the coordinate systems matching and the outlook for further data processing are discussed.

2. Methodology

The inspection data obtained using specific hardware for different NDT methods contains information on testing parameters, metadata such as inspection date, inspector, calibration parameters etc. as well as information on the component, damages found, sensitivity of the instrument, inspection parameters and other metadata about the inspection surface in the case of advanced systems. The dimensionality of data and information on the geometry are diverse for the different NDT methods such as 3D, 2D or only value for specific points (Figure 1).

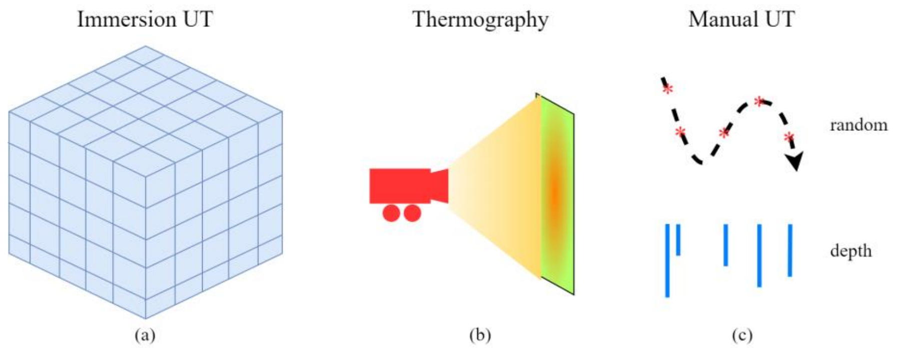


Figure 1: Datasets for different NDT methods: (a)Volume data produced from UT (b)2D data from thermography (c) 1D data for different points in a random trajectory manual UT

2.1 Inspection Methods

2.1.1 Manual Ultrasonic Testing

Manual ultrasonic testing data is used here for conversion to DICONDE and is collected using the PCUS® pro Single UT system. The inspection is performed using an Olympus V205-RM 15Mhz transducer for impulse-echo (IE) testing. The manual ultrasonic inspection device produces time-series data (A-Scan) for each inspection point obtained by a custom LabVIEW software. The position of the sensor and the component being inspected is recorded via a custom tracking system for the positions of the component and the sensor. The A-scans produced by the tool are used for the flaw detection and defect localization. The data from the system is collected via UDP and stored as *.csv or *.txt data**.** The header information of a manual inspection data file contains the hardware settings, parameter settings, inspection data and the position data from the tracking system.

2.1.2 Immersion Ultrasonic Testing

An immersion UT inspection system such as the one used here by Hillger NDT GmbH [7] produces data based on the A-scans from the component and produces the inspection results using the Hillgus ultrasound software. A multi-layer component is scanned with through transmission and IE techniques using a 10 MHz probe. The proprietary data format has the extension *.hgy. The file consists of the parameters used the for the study such as scan coordinates, resolution of the inspection, inspection date and time and details on the probe and hardware configuration. A-Scans are recorded in an equidistant 2D pattern.

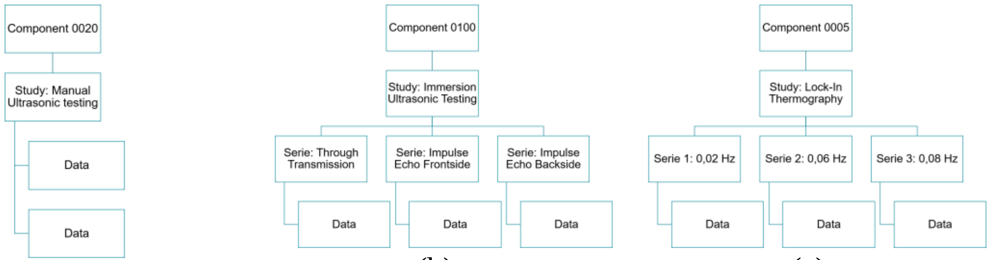
2.1.3 Thermography Testing

A FLIR bolometer is used to conduct lock-in thermography. Infrared emitters in the wavelength range around 1.1 micrometers are used for thermal excitation of the component under study. The raw data generated is available in *.tdms (proprietary data format of the company National Instruments) format together with the test, recording and excitation parameters. The analysis results are exported in *.png format for further processing.

2.2 DICONDE

DICONDE is a documented data format and as a standard describes how NDE image/signal data are to be stored and archived. The standard was developed as a solution to overcome the issues from data obtained using multiple modalities. The plan of ASTM is that this standard should be widely adopted, implemented and integrated to allow for the exchange of data between different NDT modalities. The first version of DICONDE was introduced as ASTM standard E2339 [6]. The additions for UT, ET and CT followed later [8].

DICONDE files are similar to the DICOM files. The binary files consist of two parts. The first part consists of a header with the metadata and the second part contains the image or the pixel data. The header file contains information for the hierarchical organization (Figure 2). The patient attribute used in DICOM and this attribute was changed into the component attribute in DICONDE format. The relevant metadata from an inspection are be described by DICONDE tags of the attributes with its unique keyword. The attributes help to characterize the NDT equipment, the component, the geometry of the component etc. Figure 2 denote inspections using three different NDT methods. The study denotes the modality used for the testing. The “serie” are the different scans undergone by the component and the final data denotes the instance.



(a) (b) (c)

Figure 2: DICONDE hierarchy for different components and different NDT inspections (a) Manual UT, (b) Immersion UT and (c) Thermography

2.3 Conversion

The contents of the raw data files can be analysed using different python libraries or standard open tools available to understand the contents and obtain relevant insights from the header information. The transformation of the raw data files to DICONDE can be realised using open source tools such as DICOM Toolkit (DCMTK) [9] and/or pydicom [10]. The pydicom library is used in this paper for the conversion, testing, verification and validation of the DICONDE format files (Figure 3). The pydicom library is primarily based on DICOM. For the usage, a part of the dictionary on pydicom was modified to formats based on DICONDE.

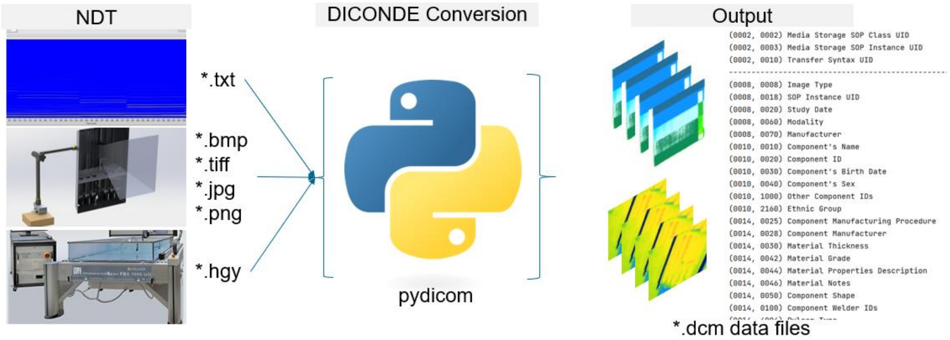


Figure 3: Pathway for the conversion of multiple types of NDT data to DICONDE

3. Discussion

The conversion of the unstructured and raw data files to the DICONDE standard based DICOM files proved to be suitable for a unified common structure compared to the data from individual NDT inspections. Additionally, DICOM files allow for a detailed information about the inspection through its attributes and modules. Thus this way of organization as a standard contributes to the descriptive, administrative and structured metadata compared to the raw and unstructured data from inspections. The usage of Unique Identifiers (UID) makes the inspection processes and studies traceable and thus may enable better data post-processing. The data organization in DICONDE enables a better organization of the inspection, which is very useful in the case of a large number of components. The use of private tag dictionaries can also enable the addition of extra information that has not yet been addressed in the DICONDE standard. However, the goal should be an extension of the standard, if required. An extensive use of custom tags would contradict the idea of creating a common data structure.

3.1 DICONDE compatible tools

The compatibility of the DICONDE format enables it to be loaded into any application supporting DICOM, such as 3D Slicer, ImageJ etc. for further processing and visualization. The open-source tools such as Weasis, MicroDICOM and JIVEX Viewers are used to study the generated DICOM files. Thus, compared to the raw binary file explorer or raw data exploring tools the DICONDE format helps without much documentation to study a large number of components inspected using different modalities. Since the DICONDE format is based on DICOM, the existing tools mentioned above read the data as Patient instead of Component (Figure 4).

(0008,0060)	Modality	US
(0008,0070)	Manufacturer	Hillgus fuer Windows (C) 2011 Ingenieurbuero Dr. Hillger, www.Dr-Hillger.d
(0008,1030)	Study Description	Ultraschall (Wasserbad)
(0008,103E)	Series Description	Vorderseite IE 10MHz
(0010,0010)	Patient Name	Bauteil CFK
(0010,0020)	Patient ID	0100
(0010,0030)	Patient Birth Date	20211213
(0010,0040)	Patient Sex	O
(0010,1000)	RETIRED_ Other Patient I Ds	0100
(0010,2160)	Ethnic Group	33 layers of HexPly and Steel
(0014,0025)	Component Manufacturing Procedure	Autoclave process
(0014,0028)	Component Manufacturer	DLR Braunschweig, FA
(0014,0030)	Material Thickness	0.4
(0014,0044)	Material Properties Description	HexPly M21/56%/1080, Spring steel 1.4310; t=0.125mm; b=300mm

Figure 4: Screenshot of the DICOM Tags in the Microdicom tool

3.2 Alignment of datasets

The challenge in manual ultrasonic testing and the final fusion of the data is the organization of the image/signal data obtained using the manual ultrasonic sensor (Figure 1). The value generated from the trajectories of sensor movement, 2D data from thermography or volume data require a common coordinate system used as a reference. The information on coordinate systems for 2D data and volume data can be comparatively easily integrated in the NDE Geometry module. The data from the use of suitable tracking technologies based on the localisation of the ultrasonic data to the coordinate system of the component requires to be integrated in the format. The Coordinate System Transform Sequence contains the data describing the transformation data needed from the base axis coordinates to another coordinate system. The transformations take place already during inspections if the local coordinate system is used as a reference as indicated by Wilken et al. [7]. This method can thereby eliminate the need to mention the about the transformation of the coordinate system. The standard thereby needs to be adapted/extended to include the new tracking systems for efficient merging and alignment of datasets from multiple inspections that produces trajectory-based data.

3.3 Challenges and further scope

1. The application of DICONDE is challenging due to the limited availability of open-source tools and applications that are capable of reading the attributes and tags that are based on the DICONDE format. This can be challenging for integrating data from other sources.
2. The quality of data from multiple modalities can be different and there is a need to develop appropriate methods to unify data for proper data fusion.
3. The use of the standard is still limited and requires public and open data for the development of the existing tools and libraries based on DICONDE.
4. The DICONDE standard is still based on DICOM and the full potential of this format can be exploited by further development of open format tools and publicly available examples of this format.
5. The non-image data such as from manual UT requires further extension for an integration of the data in this format.

4. Conclusions

The use of open data formats and standards helps in the multimodality data fusion and thereby the extraction of more information than what can be obtained from a single NDT method. The interoperability and automation of data processing and analysis can be improved using standard formats such as DICONDE. Further usage of DICONDE for NDT and the use of data fusion can be the best when the standards cover all modalities that are frequently used. New open source tools for DICONDE should be developed to assure that there is a foundation for further development and integration of this standard.

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