VISUALISATION OF ULTRASONIC TESTING DATA USING AUGMENTED REALITY

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Abstract. Ultrasonic testing data is usually visualised in form of C- and D-images. For simple inspection tasks of flat samples, these representation methods are an effective means for identifying and evaluating defects. However, for complex inspection tasks, e.g. testing of large curved composite structures, it is often difficult to relate the findings to the tested structure. Therefore it is important to illustrate the data in a more intuitional way. One approach to master these challenges is to display the ultrasonic data in an 'augmented reality' (AR) environment.

AR is a computer-based technique supporting the human perception by merging visual images with artificial, computer-generated data. With regard to ultrasonic testing, the AR technology can be used to merge the ultrasonic testing data (e.g. a C- or D-image) with the visual image of the structure. In this way, the ultrasonic image gets visually linked to the tested component and appears less abstract and more tangible than the bare C- or D-image. Furthermore, the blended image facilitates the evaluation of the data and the distinction between actual defects and structure related anomalies.

The scope of application of the AR technology is not only limited to ultrasonic testing, but provides also benefits for other NDT methods, e.g. eddy current testing. The present work gives a first impression of the potential of the AR technology for ultrasonic testing on the basis of defective CFRP structures.

1. Introduction

In the past decades, ultrasonic testing has become a well-established method for non-destructive testing.

In modern ultrasonic testing, data is usually imaged in form of so called "C- and D-images". C-images visualise the maximum amplitude as a function of the planar coordinates x and y. D-images, in contrast, present the runtime at which the maximum amplitude is recorded. Based on the maximum amplitude (→ C-image) the testing personnel determines the location of defects and judges their severity. The runtime of the maximum amplitude (→ D-image), in turn, tells the testing personnel at which depth the supposed defect is located.

Both, C- and D-images are effective means for inspecting and evaluating simple damages. However, for complex inspection tasks, C- and D-images are often hard to interpret and provide too little information to get a holistic picture of the damage. This is due to the fact, that there is no link between the findings in the C- or D-image and the visual appearance of the tested structure. One example is testing of curved composite structures. In this case it is often hard to distinguish between actual defects and structure related anomalies, especially when there are no obvious damages at the outside of the structure. In general, there is a high demand for more intuitional ways of visualizing NDT data. One way to overcome this problem is to create a visual link between the testing data and the tested structure. This can be done by visualising the testing data in an augmented reality (AR) environment.

2. Augmented Reality

2.1 Basics of augmented reality

The term “augmented reality” designates techniques that *augment* the visual real-time image of an object or the environment with additional, computer-generated information [1,3]. For this reason, it is often said that the computer-generated information is visualised in an “augmented reality environment”.

Today, AR systems have been established in many areas of industry and everyday life [1]. Some well-known AR techniques are the display of speed or navigation information in the head-up-display of a car and the overlay of graphically adapted information in a sports television broadcasts, e.g. the graphical marking of the distance to the goal in a soccer match.

The original objective of AR techniques was to provide the user with additional information, thus supporting his perception and generating a more comprehensive picture of the environment or the object of interest. Nowadays, AR techniques also serve a variety of other purposes, e.g. for entertainment.

A basic requirement that characterises AR techniques and distinguishes them from simple overlays of graphic information and real-time images is the adaption of the graphical information to the scene. In other terms, there must be a context between graphical information and the visual image or the environment. As a consequence, the content of the information must change when the visual image changes.

2.2 Hardware

A basic AR systems consist of three components: sensor, data processor and display medium [2,3] (Figure 1).

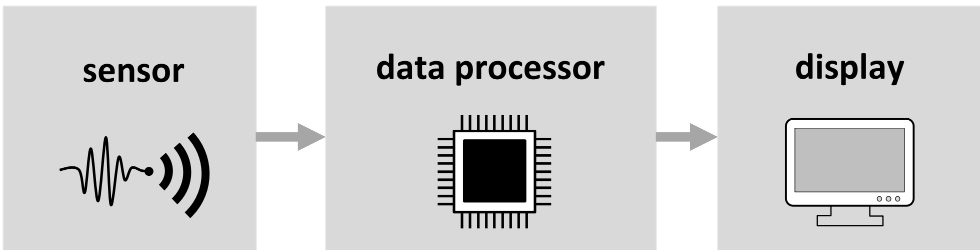

Fig. 1. Schematic visualisation of the basic design of an AR system.

The sensor represents the input element of an AR system. The sensor signal is used to determine where to place or how to adapt the computer generated information. This can be GPS-sensors, accelerometers, gyros, compasses, cameras or a combination of these.
The output signal of the sensor is fed into the data processor. The data processor represents the link between the sensor and the display medium. It analyses the signal of the sensor, identifies and tracks objects and generates the graphic output signal that is fed into the display medium.

The display medium, in turn, images the computer generated information and establishes the graphic overlay with the visual image. There are various devices that might serve as a display medium, e.g. a computer monitor, a smartphone display, a tablet, AR glasses or a video projector. AR systems which use a computer monitor, a smartphone or a tablet as display medium require a camera that records the live image and visualises it together with the computer generated information. AR glasses and video projector based systems, in contrast, project the computer generated information right into the field of view of the user and thus do not necessarily require a camera. However, if the adaption of the computer generated information relies on a marker based tracking, a camera is indispensable.

2.3 Tracking and registration

In order to match and visually adapt the computer generated information to the visual image, the computer generated data and the visual image need to be referenced. This is necessary, as the data processor needs to know where to fit the computer generated data in relation to the visual image in order to achieve the desired overlap. Because of this reason, the relative position and orientation of the observed object have to be determined continually. In this context it is said that the object is being "tracked".

Tracking can be realised in many different ways, e.g. magnetically with the help of a compass, by an inertial sensor which monitors acceleration or inclination, mechanically with the help of a distance or force measuring sensor or optically with the help of a camera [4]. Among these, optical tracking is most important.

Optical tracking methods can be subdivided into two categories: "Markerless tracking" and "marker based" tracking methods. Markerless tracking is based on recognition and tracing of characteristic features. Marker based tracking, in contrast, relies on recognition and tracing of markers. Markers are adhesive labels that feature a characteristic pattern (see Figure 2). They are attached to the object of interest and serve as a visual reference. In contrast to markerless tracking methods they allow a more precise recognition, especially when the object that is to be tracked shows a weak contrast with its surroundings.

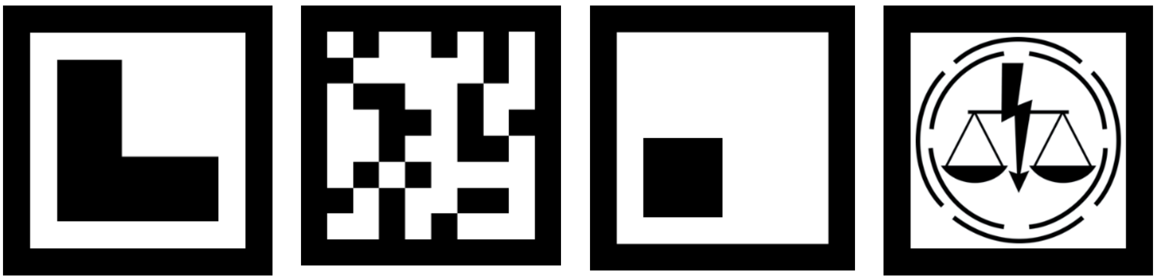

Fig. 2. Examples of AR markers.

For tracking, various image recognition algorithms can be used. Today, powerful software libraries allow easy implementation of marker tracking for an imaging device.
Once the marker or object has been tracked, the computer generated data is registered. In this context, the term "registration" denotes the fixing or embedding of the computer generated data in the AR environment [5]. In simple terms, registration can be considered as the visual adaption of the data. It comprises not only positioning but also sizing and rotation of the data.

3. Augmented Reality in NDT

AR systems have proven beneficial in a wide range of areas. For NDT the primary advantage of AR systems is the fusion of the NDT data with the visual image of the tested object, which simplifies interpretation and evaluation of test results. Especially with curved structures this proves very effective as the NDT data, which is usually imaged in flat 2D plots, gets adapted to the actual surface profile and appears more realistic.

Another advantage of AR systems is that NDT data can not only be imaged in structurally adapted, curved plots, but also in 3D. In this way, it is possible to include not only lateral information within a plot but also vertical information. This proves particularly beneficial for issues where depth resolution matters. With regard to ultrasonic testing, for example, it is possible to combine the information of a C-scan and a D-scan in a single image.

The present section highlights the potential of AR systems for NDT. For this purpose, three exemplary applications are presented and explained in further detail.

3.1 AR glasses based visualisation of ultrasonic testing data

Figure 3 shows an exemplary application of AR glasses for visualisation of an ultrasonic C-image. Depending on the spatial perspective the C-image is visually adapted to the CFRP structure. In this way, the user who carries the AR glasses gets the impression that the C-image forms a unity with the structure. Especially with curved structures this effect is very beneficial as the user gets a spatial, three-dimensional impression of the damage, thus supporting its evaluation.

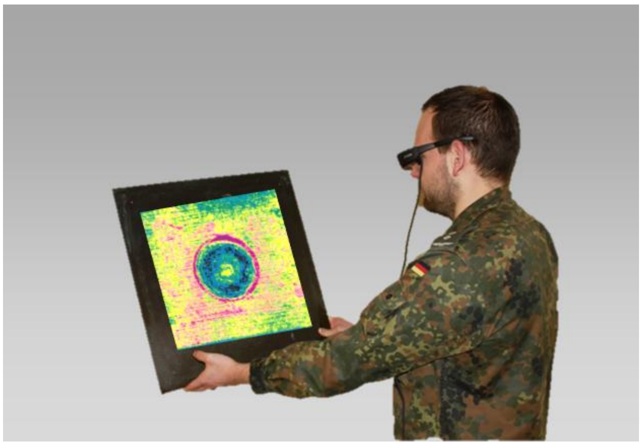

Fig. 3. Visualisation of an ultrasonic tester inspecting a CFRP structure with AR glasses.

3.2 Tablet based visualisation of ultrasonic testing data

Figure 4 shows an exemplary application of a tablet for inspection of an impacted CRFP sheet. Just as with the AR glasses, the C-image is continually adapted to the tested structure and gives the impression that the C-image is actually part of the structure.
The tracking is done with the help of a marker that is attached to the bottom left corner of the structure.

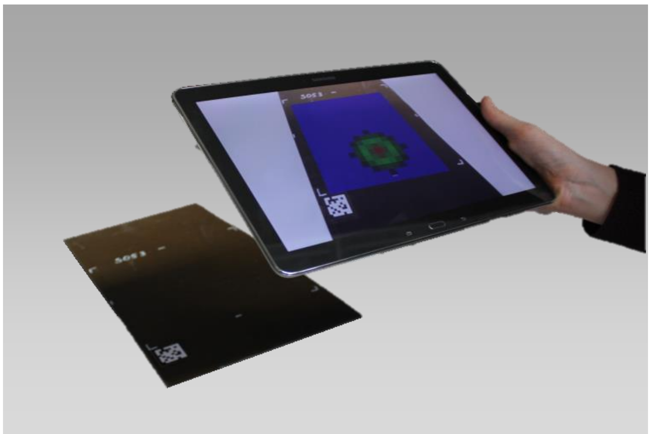

Fig. 4. Tablet based visualisation of an exemplary C-image of a CFRP structure in an AR environment.

3.3 Video projector based visualisation of ultrasonic testing data

Figure 5 shows a video projector based AR environment. In this case, the video projector is used to image ultrasonic testing results right onto the surface of the tested CFRP structure. Similar to the aforementioned examples, the AR environment helps to establish a spatial, three-dimensional impression of the test results.

In case the position of the video projector and the tested structure remain fixed, the referencing, i.e. the overlay of the C-image and the structure, can be done manually. However, if a dynamic adaption of the C-image is desired, continuous tracking is required, e.g. with the help of a marker.

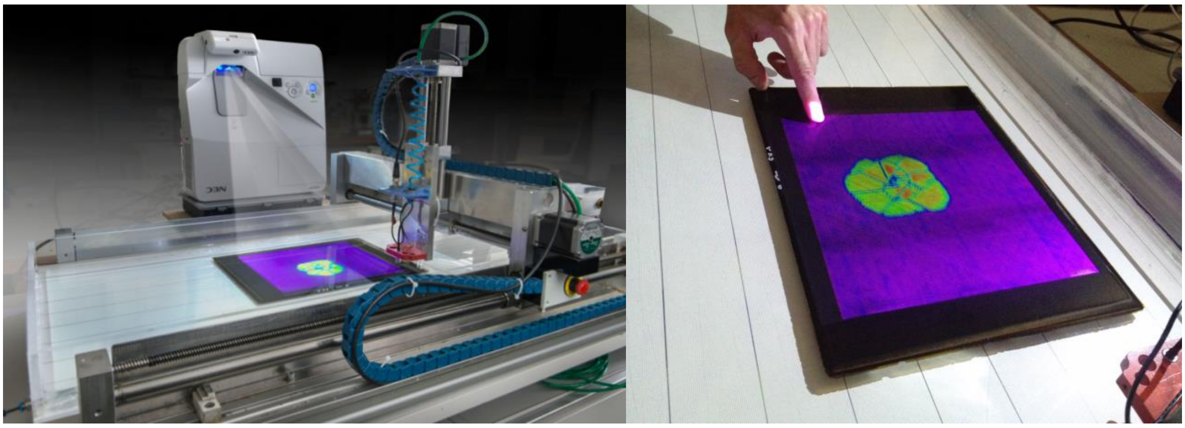

Fig. 5. Video projector based visualisation of a C-image in an AR environment (left: overview, right: projection of US-NDT results on CFRP sheet with impact damage).

3.4 Challenges of AR based visualisation of NDT data

AR is a mature technique that has been established in various fields. However, with respect to the visualisation of NDT data there are some challenges to be tackled.

First, the marker has to be referenced with the imaged NDT data. This can be done manually by defining the spatial position of the marker in relation to the NDT image. However, for the purpose of user comfort it would be beneficial to reference the marker automatically. This could be realised with the help of "hybrid markers". Hybrid markers not only feature visual characteristics, but also characteristics that are sensitive for the respective NDT method. For ultrasonic testing, for example, it would be advisable to use markers which not only show visual but also acoustic characteristics. Similar to the visual black and white patterns, these markers could feature an acoustic pattern with strong reflective areas and low reflective areas. Due to the high contrast between strong and low reflective parts, this pattern could be easily recognised in the NDT image and thus serve as a marker.

Another aspect that has to be approached when using AR technology in context with NDT is the determination of the surface profile. In detail, if the tested structure shows a curved surface, the surface profile must be known for adapting the NDT image onto the surface. Otherwise the NDT image will appear planar, thus losing the spatial, three-dimensional impression that should be attained by the AR technology. However, this issue only affects curved structures. In case of planar structures, the determination of the surface profile is not an issue as the as NDT image does not need to be visualised in a curved shape but can be readily imaged onto the surface.

4. Results

The three exemplary applications show that AR technology offers great potential for imaging NDT data.

With the help of AR technology, NDT data is visualised together with the visual image of the tested structure, thus giving a spatial, three-dimensional impression of the testing data. In this way AR technology can assist the interpretation and evaluation of NDT data. These advantages particularly affect NDT data of curved structures, as the AR based imaging reduces the degree of abstraction and supports the spatial perception.

For convenient tracking of NDT data it is beneficial to use hybrid markers that feature not only visual but also NDT sensitive characteristics.

5. Outlook

The scope of AR technology is not limited to visualisation of individual NDT results, but also covers simultaneous visualisation and merging of various test results. For example, it AR allows to display multiple images from different areas of a structure at the same time, thus revealing similarities or periodicity of damages.

Another form of application that offers even greater potential lies in sensor fusion. In this connection, AR technology can be used to merge or overlay test results that were obtained with different NDT technologies, e.g. ultrasonic and eddy current testing. In this way, it is possible to combine the individual advantages of different NDT technologies and compensate for their shortcomings. As a result, the AR generated image includes more information and is easier to interpret than the individual NDT images.

References

[1] KIPPER, Greg; RAMPOLLA, Joseph. Augmented Reality: an emerging technologies guide to AR. Elsevier, 2012
[2] CRAIG, Alan B. Understanding augmented reality: Concepts and applications. Newnes, 2013
[3] FURHT, Borko (Hg.). Handbook of augmented reality. Springer Science & Business Media, 2011.
[4] TÖNNIS, Marcus. Augmented reality: Einblicke in die erweiterte Realität. Springer-Verlag, 2010
[5] DÖRNER, Ralf, et al. (Hg.). Virtual und augmented reality (VR/AR): Grundlagen und Methoden der Virtuellen und Augmentierten Realität. Springer-Verlag, 2014