Benefits Achieved by Applying Augmented Reality Technology in Marine Industry

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Abstract

In this paper we describe potential use cases of augmented reality technologies in marine industry. In the two-year research project on-going at University of Turku we develop a mobile tool which enables visualizing 3D-CAD models and related information onto real environment and accessing data based on location in 3D-CAD model. The tool is designed to be used in industrial environment. The tool can be used to replace paper blueprints at the workplace and to increase efficiency in inspections, reviews, planning, reports and project plan follow-up. Potential use cases include for example documentation, virtual notes, inspections and installation checks. The research team has identified a number of use cases and analysed the benefits that can be achieved especially by applying augmented reality technologies. Finally, selected pilot use cases are described in detail.

Keywords—Mobile augmented reality; marine industry; ship building

1. Introduction

This paper presents the current results and analysis done in *Mobile Augmented Reality Tool for Marine Industry* project (MARIN) in the University of Turku. The paper is structured as follows:
Section 2 describes briefly the MARIN project, then clarifies the basics of augmented reality and discusses potential applications of augmented reality in industry, and especially in marine industry. Section 3 explains the requirements for those applications and the system implementation. Section 4 describes the actual use cases implemented in MARIN. Finally, the achieved results and future plans are discussed in Section 5.

2 Background

2.1 Project Description

MARIN is a two-year research project on-going at University of Turku; it will end in mid-2014. The project aims at identifying potential applications of augmented reality for marine industry and developing a demonstration tool to prove the functionality of the technologies as well as test the usability and benefits in the selected use cases. MARIN is carried out in collaboration with several industrial partners including software, CAD-design, mobile technology and maritime companies.

The expectation in this research project is that overall efficiency and quality in design, documentation, project follow-up, reviews and inspections can be improved and cost savings can be achieved with the use of augmented reality solutions.

2.2 Augmented Reality

Augmented reality (AR) technology enables overlaying virtual information – like plans, models or instructions – on real environment *(Azuma 2001).* The user can either see the augmented view on computer's, tablet's or smartphone's display, or ultimately the augmented reality can be viewed through a transparent head-mounted display. In the first case user sees a live video of the surroundings and virtual data is augmented on top that. In the case of a transparent display, the user sees actual surroundings through the display, and virtual information is added in the correct position and projection in the user's view.

Several projects, e.g. *Friedrich & Al (2003); Lukas & Al (2003)*, have studied industrial use of AR applications for visualised service, maintenance and assembly instructions and renovation work. Many applications have been developed, e.g. in automotive industry, as research projects. (*MARTA, BMW Service AR Workshop*). Consumer-oriented applications exist as well (*Audi eKurzinfo*).

In industry, there is a great number of suitable applications for augmented reality. Potential benefits that can be achieved by it include the following:

- AR allows keeping the most up-to-date CAD model and design information always available and visualised intuitively in real environment. This reduces the need for paper blueprints, which may be outdated.
- Information from actual construction site, referring to the details in a CAD model, can also be transferred quickly to designers and reviewers and used for documentation purposes.
- AR displays (or viewing virtual 3D models) may help interpreting the plan, compared to traditional blueprints that present the data in 2D only.
- Instructions for installations and repairs can be presented using augmented reality.
- Telepresence solutions allow an expert to give guidance in a repair task without being personally at the location.
- In shipbuilding projects, various inspections and reviews can benefit from AR. The user can check 3D CAD models against existing reality to see if construction has been done according to plans, and to document actual construction. AR tools can assist when checking equipment and supplies. In other words, augmented reality can be applied to project follow-up also. Fig. 1 illustrates a use case where pipe installations are observed using a smartphone as an AR display.
- User can attach on-line notes and remarks to a specific part or model during construction and review.
- An augmented reality tool can be used to check routings, for example, in case when big equipment needs to be transported into a location inside the ship. A suitable route can be planned in advance by virtually transporting the model of the equipment through the anticipated route. Similarly, in renovation case it can be checked in advance how the new equipment can be installed into the place of the old one.

2.3 Use Cases in MARIN Project

The potential augmented reality use cases in marine industry are largely similar to those in other industry areas. The MARIN project has identified potential use cases within marine industry, some of which are valid only in building phase, some in maintenance, service and renovations, so the whole life cycle of the ship is covered. The following cases are examples of those:

- Inspections – e.g. checking installations or statutory equipment
- Measurements of length, distances etc.
- Installation instructions and outfitting support tool
- Modification of the 3D model – e.g. adding new openings
- Displaying element and system information – what is the material and purpose of this part? (Fig. 1.)
- Indoor localization and navigation – e.g. finding the way out
- Seeing behind the wall / bulkhead
- Photography and other documentation
- Virtual notes (online notes virtually located in the ship)
- Classification surveys of fire boundaries

- Classification surveys of machinery

Fig. 1. Illustrative example of using a smartphone for augmented reality viewing of pipe installations. The system may e.g. present information about the purpose and material of individual pipes.

A handful of these cases were selected for further study and implementation of a demonstrator. A good case for demonstration purposes would bring out possibilities for innovation from AR point of view and have potential for financial savings. So it should be feasible to develop a solution for the case in the project, it should be common enough, and the AR tool should have potential to save time and/or reduce possibility of errors compared to traditional work methods. Some of the listed applications would require specific techniques or equipment and were therefore rejected – for example, accurate measurements of dimensions aren't possible using camera data only.

The specific cases selected for further work were:

- Documentation, including photos
- Making a request for an opening
- Virtual notes
- Inspections
- Localization and routing
- Classification surveys of fire boundaries

The three first cases are discussed further in this paper.

2.4 Documentation and Virtual Notes

Documenting the progress of building a ship is a major task. Photography is one essential part of documentation. To be useful (e.g. to allow search), the relevant metadata for the photos must be recorded: where and when the image was taken, what it contains and so on. Often it is useful to add comments to a photo, too. AR can improve the on-site viewing experience of photos e.g. by showing the locations of the photos.

Annotation of parts, locations and equipment is another common documentation need. Many kinds of markings, simply drawn by hand, can be seen on the parts of a ship under construction. In addition to these, an AR solution would offer the possibility to use virtual (or online) annotations, made and observed with the AR system. Online annotations have certain benefits over the traditional ones. First, the annotations would be accessible also elsewhere than the actual construction site. Anyone observing the 3D model of the ship would be able to see the annotation. Second, they may contain additional audio-visual data, like a photograph or a spoken comment. Third, these notes will not be hidden under layers of paint, insulation or equipment installations.

AR-assisted documentation is expected to improve quality and make it easier to find and use the information afterwards. The demonstration of this case will be discussed in section 4.1.

2.5 Opening Request Case

Adding openings to decks and bulkheads is a special case of using the tool to make modifications to plans. It happens frequently that an opening for certain piping or wiring does not exist in the hull model, and therefore in the actual bulkhead or deck plate, when a ship block is being built and outfitting starts. This is due to the design of subsystems going on in parallel with the building of the hull. An example of an augmented reality application to support pipe layout planning is presented in *Olbricht & Al.* (2011). Before new openings can be cut, they must be approved by the engineering staff, to make sure they do not cause strength or other risks for the vessel.

The number of late added openings in a big vessel can be high. Especially in case of unique vessels, like cruise ships, where subsystems are not completely designed when the construction of the hull starts, the total time and cost savings can be significant. The AR tool is expected to save costs via less rework in construction, and in addition to make it easier to document and agree the changes. The demonstration of the case will be discussed in detail in Section 4.2.

3 System Description

The MARIN AR system (Fig. 2) is built around a mobile central unit, which may be a tablet or a smartphone. External units are connected to it: a camera, optional data glasses and sensors. This section describes the requirements and challenges for the system and the chosen technical solutions.

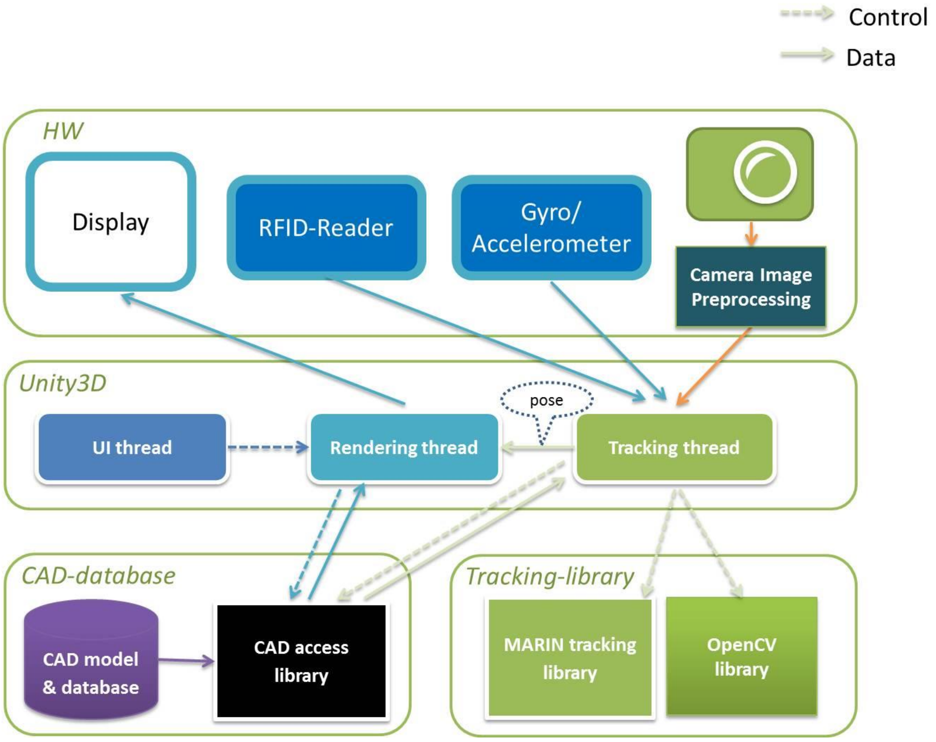

Fig. 2. MARIN project technical architecture

The MARIN system consists of:

- A Windows 8.x tablet or phone as the central processing unit and display
- Camera (and/or HW accelerated camera)
- Inertial sensors (accelerometer, gyro) attached to the camera/display
- Unity 3D SW
- OpenCV software library for tracking
- See-through AR glasses (optional)
- RFID reader

3.1 General Requirements

Portability

An important requirement is that the equipment must be light and easy to carry with. The intention is that a smartphone or a tablet computer, possibly together with AR glasses, would be used. For user interface, "hands free" operation is preferred, so for example voice recognition may be an option. Additional infrastructure needed for the system should be minimized; the aim is to use systems that exist already for other uses. It depends of course on the cost and work amount for installation, if something specific is acceptable.

Sufficient Usage Time between Charges

Tool operation times must be long enough to carry out at least half a workday without maintenance, and charging should be possible within ~1 hour. The usage time requirement affects the choice of equipment.

Robustness and safety

The tool must be suitable for ship and shipyard environment, resist dust and moisture, and must able to take some rough usage. General safety requirements must be fulfilled. Due to safety reasons, see-through transparent AR glasses are preferred over video (virtual reality) glasses. Safety issues affect also UI design: displayed elements should not block the user's view during user movement, for example.

3.2 Technical Description

The ship and shipyard environment set difficult challenges for the implementation and technologies. A lot of metallic structures are used and those impact heavily on radio signal propagation, magnetic and electrical fields. There may be areas where it is not possible to make data connection with GSM/WLAN, or the data connection is unreliable. Also the environment is changing all the time during construction as new structures, modules, equipment and furniture are installed into the ship.

This means additional challenge to coarse position estimation, i.e. estimating the approximate position of the system. The accuracy of this estimation must be high enough: the system must be able to tell in which room or corridor the user is. Current approximation is that accuracy of 1–2 meters would be enough for rough scale estimation, but possibilities for errors still remain, e.g. the system may define the location to the wrong side of a wall. System needs to offer user interface functions to handle these efficiently and sometimes even manually. For coarse position estimation, an RFID based system was chosen *(Helle & al. 2013)*.

For fine positioning we use image analysis software fed by a web camera in the system (Fig. 2). Gyro and accelerometer data is planned to be used in parallel to improve reliability in case the visual tracking fails. Latency target is below ~30 ms to prevent/reduce the possibility of sickness due to delayed view, when using data glasses.

3.3 Integration to Information Systems

The full benefit of the tool can be achieved only if it is seamlessly integrated to shipyard's information system and databases.

The integration requires a communication link between the tool and the information system. The link could be based e.g. on WLAN. However, it is difficult to realize a continuous and reliable link in a ship that is under construction. Therefore, the tool must be able to operate offline inside the ship and be able to synchronize itself with the information system when the link is available during work breaks.

The integration requires also access to various information sources, for example to blueprint and material databases. Some data format conversions and content adaptation will be needed for proper interoperability. There must also be a way to store data to the databases, for example for documentation purposes, and to send feedback to the information system (e.g. new opening request).

3.4 Localization and Tracking

3.4.1 Overview of Pose Tracking

It is essential to know observer's pose, i.e. location and viewing direction, to properly register the virtual content to observer's view. The pose must also be kept constantly up-to-date, i.e. it must be tracked, when the observer moves or changes his or her viewing direction.

For example in tourist guide type applications, like *NOKIA* City Lens, a common approach for pose tracking is to use GPS device for localization and compass to find out the viewing direction. This solution works adequately when the observer is outdoors and the pose need not be known accurately. However, in our case this approach is not nearly sufficient: GPS and compass do not work inside a metal structure, and they are not accurate enough. We must use visual tracking from camera data.

A common visual tracking solution is marker-based tracking, where easily recognizable, unique markers are placed in known locations within the working environment. This technique is well-known, relatively robust and not too computation-intensive. One example of marker usage is presented in *Naimark and Foxlin (2002)*. The problem is that the number of markers needed becomes huge if tracking should be supported anywhere in the ship, and thus the maintenance costs would be high.

MARIN has decided to go with model-based visual tracking. In it, image feed from a video camera fixed to the observer is compared to a model of the surroundings. If enough model features can be identified from the image, then the observer's pose can be calculated. This approach does not require specific visual markers, but it is not alone sufficient for completely automated localization – there are many places with similar visual features within a ship, so we need additional means for defining the approximate location, too.

3.4.2 Pose Initialization

The first step in the initialization of the pose, so that actual tracking can start, is to identify the approximate position of the observer. MARIN uses RFID tags for that. *Helle & al, (2013).* RFID identification tags are distributed in the ship so that in most locations at least one should be readable with an RFID reader. Motion sensors in the system can be used to track user movements and location, filling in possible gaps in RFID coverage. The user has also other, manual input options to specify the current room in case any RFID signals would not be available.

The second step in the initialization is to match video camera image features to model features. MARIN uses detected corner points and lines for that purpose. It is not easy to fully automatize this step; one reason being that there can be ambiguous details in the environment that make it hard to deduce what the actual pose is. Due to that, a user guided initialization technique was implemented. In it the model is rendered on top of the video camera image and the user then matches the model corners to structure corners by pointing at the corresponding model and structure corners on screen. The device can aid the user for example by highlighting the corners near the cursor and by automatically snapping a pointed point to the nearest detected corner. We aimed at designing an easy-to-use initialization method so that the user only needs to roughly align the model with the image and the equipment does the final matching automatically.

3.4.3 Pose Tracking

After the initialization, the matched corner points on video image are tracked using well-known 2D optical flow techniques *Lukas, Kanade (1981)*. The corner point tracking allows a new pose estimate to be calculated per each video frame, thus allowing the pose estimate to be kept up-to-date all the time.

It is inevitable that some of the tracked corner points are lost every now and then. For example, a corner point may fall out the video image, the point may be occluded by some obstacle or video image motion blur may make it impossible to locate the point any more. Therefore it is essential that the device automatically adds new matched points whenever possible.

Gyros and acceleration sensors can be used to assist the visual tracking method. For example, the sensors can give hints about the direction of the user movements, or the sensors could be used as a backup tracking method if a user is so close to a wall that there are not enough corners in the camera field for the visual tracking to be able to work. Inertial sensors can only calculate the pose estimate relative to the previous estimate, and as time goes on the pose estimate inaccuracies gradually cumulate and the estimate starts to drift away from its correct value. Hence, tracking can be based on sensors alone only a short interval at a time. For typical sensors in mobile devices and AR glasses the signal-noise ratio may also be an issue. At the time of writing, inertial sensor data has not been taken into use in the MARIN system, although the use of it is in the plans.

3.4.4 Vision Chip Architecture for Visual Tracking

One novel aspect of this project is to study the possibilities of mapping certain parts of the pose tracking in an embedded vision chip architecture. The focus of this project is not to manufacture an actual chip for this task, but rather to find out the requirements for this kind of hardware acceleration (*Zarandy 2000*). These vision chips provide computation resources integrated to the CMOS camera itself (Fig. 3) and could enable the integration of the feature extraction part of the tracking into a compact size and very low power consumption. These requirements (compact size and low power consumption) are present in the MARIN project. Also, some of the special conditions which the usage environment sets for the tracking could be solved with intelligent pre-processing capabilities of these chips.

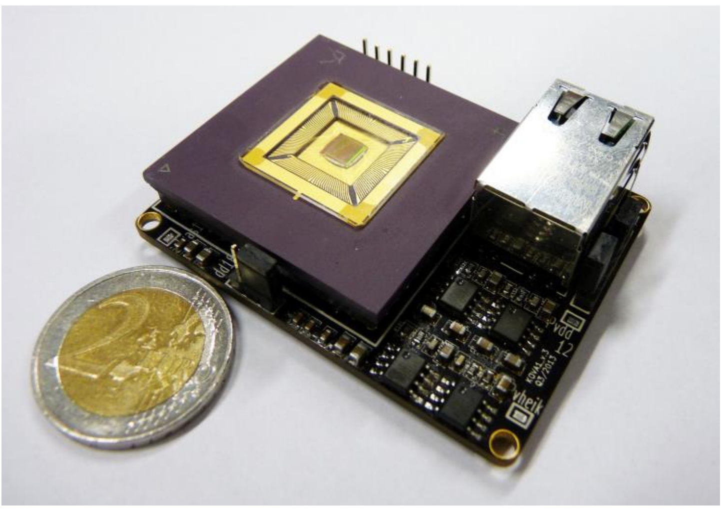

Fig. 3. KOVA1 embedded camera module by Kovilta, an industrial partner in MARIN project.

The vision chip architectures can be used to detect corner points (*Nieto*), or to estimate keypoint based image descriptors. Also, robust optical flow based tracking could be performed. The applications of these architectures are naturally not limited to the shipbuilding environment. Accelerated pose tracking devices could provide longer battery lifetime and more accurate pose estimation also in other augmented reality applications where the mobile user experience is critical.

3.5 Usability Issues

To gain the intended benefits the system must be easy and efficient to use. The following aspects are among those that must be taken into account.

3.5.1 Control of Location and Tracking

Ideally, the system should define its location automatically in the initialization phase. This may be impossible, for example, due to the fact that we cannot recognize enough features in the camera data to define the exact location with certainty, even if the coarse position would be known by the RFID data. The system may also lose tracking while moving. This is a situation that may happen frequently and should be easy to recover. The use of inertial sensors and RFID data can help to avoid losing the tracking in the first place; however we are designing a quick and easy manual method to define the pose as a backup.

3.5.2 Display

First of all, the user must be able to easily decide what to see in the virtual view. The data may contain a large number of systems and components, some of which are relevant for the current task, and others are not. System parts contain also metadata that can be shown to the user. Further on, the system can display notes, photographs and other additional data the user may or may not want. How to easily switch on and off the display of all these elements is a major challenge for user interface design. One way to avoid excess data on the display is to use a ‘focus point’ in the middle of the display, so that when the point is over some object, that object’s metadata is shown beside it, but other objects’ data is hidden.

Virtual content should be displayed in a way that is easy to interpret and delivers the necessary information. Photorealistic rendering is not necessary in this kind of application – it may even be harmful if the virtual content is difficult to distinguish from real-world objects. Wireframe rendering may therefore be a good choice; it also leaves the real objects visible through the virtual content. In some cases a simple shading method may be a better option. The user should be able to easily choose the optimal rendering style for each situation.

Viewing virtual content via see-through glasses is an attractive concept. The user’s hands are not needed to hold a display, and in the best case an immersive experience can be achieved. However, there are challenges too: keeping the perfect alignment of the eye and display, controlling the brightness of the displayed image in relation to the real environment, and the rather limited field of view in most of the current commercial products are some of the issues that need to be solved.

Promising new products are expected to enter the market (e.g. *Vuzix*, Fig. 4), and the MARIN project is looking forward to integrating also see-through glasses into the system.

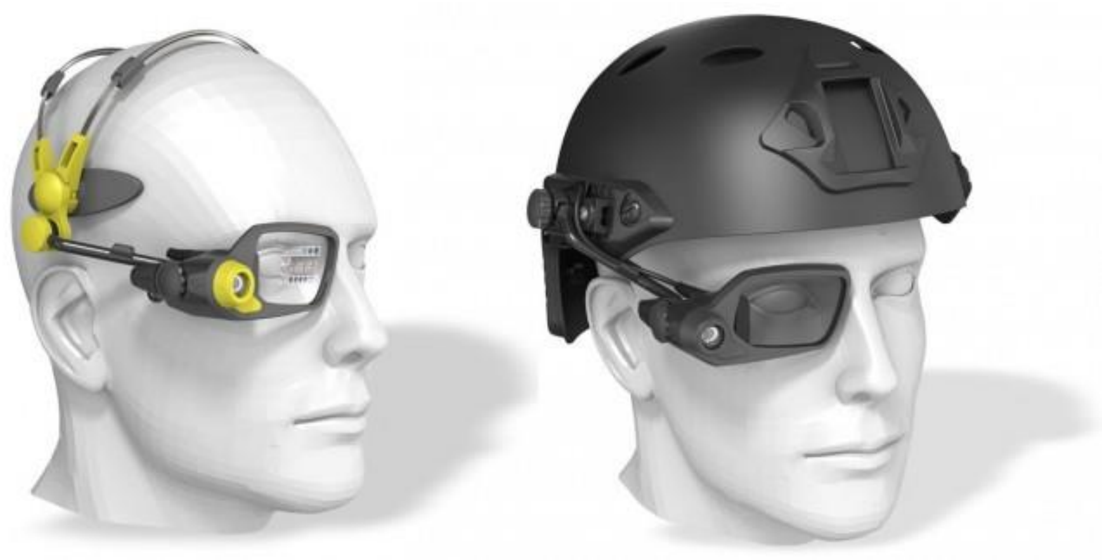

Fig. 4. Vuzix M2000AR optical see-through AR display system designed for industrial use.

3.5.3 Input

The user sometimes needs to enter data into the system. Actually, the need for this should be minimized: if the system already has some information, it should not ask it from the user. For example in the opening request case (explained in Section 4.2) all possible data should be extracted from the information that is already known by the system. Only the actually new data, like desired location of the opening and its dimensions, should be entered by the user, and done in an effortless way. Location can be defined by pointing, and dimensions can be set using simple controls and menus. When additional comments must be entered, it could possibly be done using voice recording, which is quicker and less tedious than using e.g. a touch screen keyboard. However, sometimes plain text entry is unavoidable, so there must be a solution for it also. For data glass use – when there may not be a touch screen at hand – we should offer a usable text input method. At the time of writing this article we have not implemented a solution for that.

In general, hands free control of the system is preferred so that the user could use hands for the actual work tasks. Speech recognition is one option for controlling the system, although the noise level at a construction site is often high and can make use of speech difficult.

4 Solution Demonstrators

4.1 Online Documentation Demonstrator

A documentation and annotation scheme was designed with which it is possible to leave notes virtually anywhere in the ship. (Fig. 5.) The user may annotate a photograph and add audio or textual comments to it. The system adds all available metadata to the document automatically: e.g. location, time, user's name. The user can add keywords and other information to make the document more useful.

Users can anchor the notes to a location in a 3D model. (The term *note* here covers all different kinds of virtual documents that may contain e.g. text, photographs, audio, and action requests.)

Notes are stored in a database where they can be searched based on all this data. This allows more comprehensive documentation for the work than what is currently typical in a ship project, and it makes finding specific information easier than searching among a mass of undocumented photos, for example.

Such 'online notes' can be browsed on location by looking at the AR display. The user can choose what kind of notes to look for – some notes may also be set as viewable by only specific persons, those who need to know about them. A note is displayed as a virtual object (symbol, icon) on the display, and the user can open it to view the detailed content. Notes may allow feedback and editing, so that they can be used for task managing.

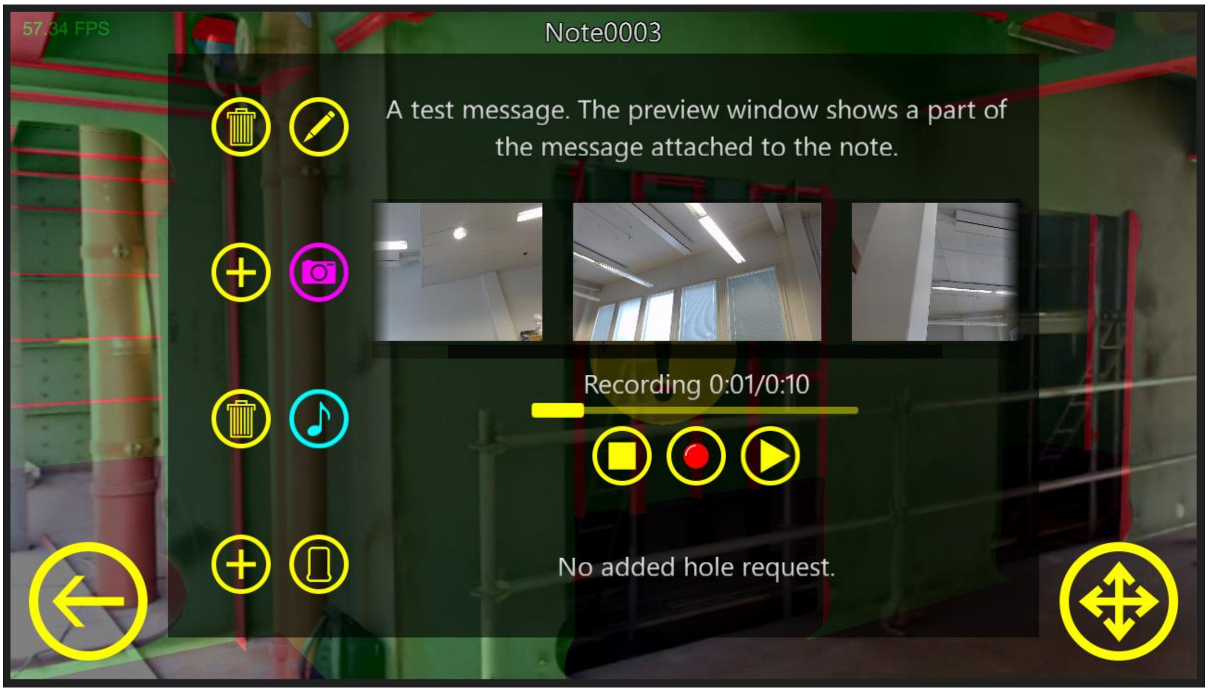

Fig. 5. Documentation application prototype. Text, photos and audio messages can be included in a note that is placed virtually in a location in the ship.

By linking documentation into a messaging system, it is possible to address a note to the recipients who should be aware of it. For example, a note about a missing or incorrect installation would reach the responsible person via messaging. After correcting the issue the note would be updated accordingly.

4.2. Opening Request Demonstrator

The process could be speeded up by an AR application that simplifies the creation and approval of opening requests. The intention is to design a fluent flow of actions for defining an opening request and handling it.

The system lets the user define the parameters of the desired opening:

- shape
- dimensions
- orientation
- location
- purpose; e.g. what piping will go through the opening

The system can show the opening virtually on the location, and the user can adjust it interactively until it looks as intended. (Fig. 6.) In case there are restrictions due to water tightness or structural rigidity, the system can display also areas where openings will not be allowed.

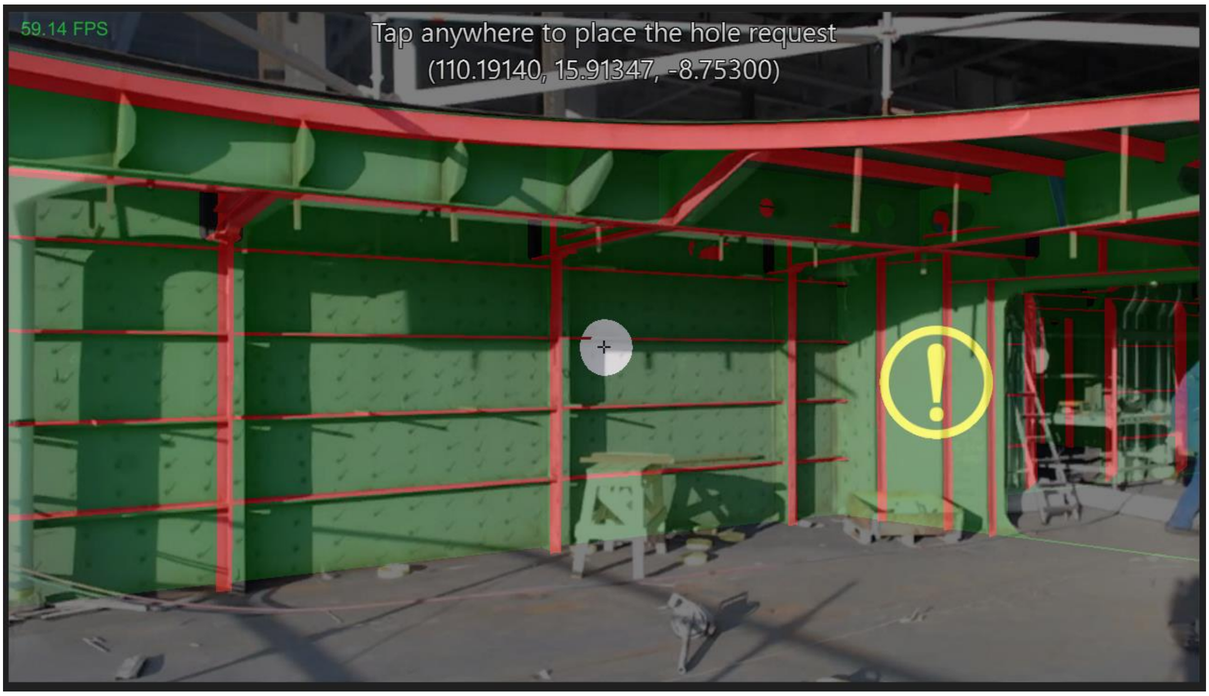

Fig. 6. Opening request application prototype screen. User sees the 3D model superimposed on real environment. The blob with a + sign is a virtual sphere used as a pointer for placing the opening onto a surface.

The user fills in the necessary data and then sends the request for approval; the system supports forwarding the data e.g. by email, in our case coded in a CSV format file. If live data connections exist, the request can possibly be handled in a short time, and approval can be sent back to the workplace. If the request cannot be approved as such, some negotiations may be needed to agree the modifications, and the system may support this too.

Running the request through this kind of process is expected to reduce the time needed for approval and thus speed up construction work. Compared to the traditional method of using paper-printed drawings and pen, the automated process can help in visualizing the details of the construction on the actual structure, and displaying only the objects of interest. It should also be able to eliminate some errors by indicating forbidden locations for openings and checking that these locations are not used in the requests.

The process also gives a possibility to add the new opening to the 3D model and document it without much extra work.

5. Conclusions

We have designed and implemented a prototype augmented reality system for selected use cases in shipbuilding industry. At the writing time of this paper, the construction and testing of the system is still ongoing. While the work goes on, we believe the demonstrated cases can show benefits in documentation, engineering and inspection tasks.

The Opening request case is a good example of how a frequent operation can be automated and work time and costs saved. The AR system knows the coordinates of the opening and can add it in the 3D CAD model automatically. Coordinates and other relevant information are stored directly to a CSV file and can be sent to the information system for handling.

The MARIN system is based on a tablet computer in the current implementation. Smartphone could be another option, especially if AR glasses would be used. The use of see-through data glasses in the system has been studied, but for technical reasons they are not integrated in the current version of the system.

Best possible results require good integration into existing production databases and IT systems at shipyards. These may differ between manufacturers and sites, so more work is needed to draw universally valid conclusions.

The experiences gained in the MARIN project indicate there is a lot of potential in applying AR technology to marine industry. We plan to continue the work in further projects that will aim at developing more complete, portable AR systems for industrial use.

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References

FRIEDRICH, W. WOHLGEMUTH, W. (2003) *ARVIKA Augmented Reality in Entwicklung, Produktion und Service*, International Workshop on Potential Industrial Applications of Mixed and Augmented Reality, Tokyo, Japan.

von LUKAS, U; VAHL, M; DEISTUNG, E; MESING, B (2003) *Augmented Reality für die maritime Industrie – Dokumentation der Ergebnisse der Studie* http://www.use-ar.de/fileadmin/user_upload/pdf/studie2.pdf

MARIN project pages http://ar.utu.fi/research/marin/

NOKIA: *Here City Lens application*, http://www.nokia.com/gb-en/apps/app/here-city-lens/

L. NAIMARK and E. FOXLIN (2002). *Circular data matrix fiducial system and robust image processing for a wearable vision-inertial self-tracker.* International Symposium on Mixed and Augmented Reality.

S. HELLE, M. KAUSTINEN, S. KORHONEN, and T. LEHTONEN (2013) *Indoor Localization Solutions for a Marine Industry Augmented Reality Tool*. University of Turku Technical Reports, No. 1.

LUCAS B.; KANADE T. (1981): *An Iterative Image Registration Technique with an Application to Stereo Vision*, Proceedings of Imaging Understanding Workshop, pp. 121-130

ZARANDY, A. (ed.) (2011) *Focal-Plane Sensor-Processor Chips*. Springer

NIETO, A., VILARIÑO, D.L, BREA, V.M. (2000) *Feature detection and matching on an SIMD/MIMD hybrid embedded processor*, 2012 IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops (CVPRW), pp. 21 - 26.

OLBRICHT, M; WUEST, H; RIESS, P; BOCKHOLT, U (2011) *Augmented Reality Pipe Layout Planning in the Shipbuilding Industry.* ISMAR 2011, pp. 269-270.

VUZIX M2000AR see-through augmented reality system http://www.vuzix.com/UKSITE/consumer/products_m2000ar.html

AVILUS – Applied Virtual Technologies in the Product and Production Equipment Life Cycle http://www.vdtc.de/en/technology-vdtc/projects-vdtc/avilus-vr-for-production-equipment-life-cycle.html

AUDI eKurzinfo http://www.audi.com/com/brand/en/experience/audi_multimedia/audi_apps/models/audi_ekurzinfo.html

MARTA – Mobile Augmented Reality Technical Assistance http://www.metaio.com/press/press-release/2013/volkswagen-marta-augmented-reality-service-support/

BMW Service AR workshop http://www.bmw.com/com/en/owners/service/augmented_reality_workshop_1.html