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Integration of smart hand tools and digital assistance systems

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Abstract

Despite industrial production becoming more automated and digitalised, manual work remains indispensable. Work tasks are still largely carried out using conventional hand tools and paper-based documents, which leads to problems in productivity and quality. Smart hand tools can improve quality by controlling diameters, rotation speed or torque and documenting recorded feedback data. To do this, they need information on the current context, such as the tool's position or the production progress. In many cases, the context is either not integrated or is programmed statically into the tools with considerable effort. Digital assistance systems, on the other hand, gather and process data about the context in order to increase productivity by displaying information for conventional manual assembly processes. However, they do not support work processes carried out with smart tools. Integrating the tools into the assistance systems makes it possible to generate content and context for the tools in a generic and efficient manner, while also supporting value-adding and tool-dependent work tasks. This paper presents such an integrated digital assistance system in detail and validates it in a laboratory environment with regard to potentials and general usability.

Keywords: Digital Assistance System; Digital Twin; Smart Tools; IIoT;

1. Introduction

Human flexibility and intelligence is necessary for the production of many products but introduces the potential of process variability and quality problems [1]. Increasing productivity and quality demands intensify this problem, underlining the necessity of digital assistance for manual work. Integrating workers into a digitalised production is a challenge that requires in-depth research beyond basic modeling and concepts [2]. There is a variety of possible applications in practice while each individual implementation requires complex initial efforts. Real-time support and process control is only effective when data related to workers activities and the dynamic production context is continuously measured and processed into actionable process inputs [3]. As proposed in [4] and [5], a scalable platform combining digital assistance systems with smart hand tools would support this and enable a broader human-centred digitalisation.

Currently, conventional hand tools are often used in combination with paper-based documents, resulting in production errors and high costs for information procurement and documentation. Smart hand tools have the potential to automate documentation and reduce errors. The prerequisite is that the tools integrate information about the current context (e.g. the tool position or production progress). For most existing systems, the context is statically programmed or inadequately generated. Digital assistance systems can gather data about the dynamic production context to support manual work by appropriately presenting information and thus improving productivity. However, only tool-independent preparation tasks can be supported and no data from smart tools can be documented. The integration of smart hand tools with digital assistance systems would make it possible to utilise the gathered context data for the tools and also support the value-adding tasks of execution as well as follow-up processes. Although initial approaches for such integrated systems can be found in large-scale production and first reference models describe the integration [6], the topic remains complex.

This paper presents an integrated digital assistance system to provide a tangible insight into a working solution. It combines a content creation application and a worker assistant application with smart hand tools and has been described conceptually in [4] and evaluated as potentially highly effective and accepted by workers in aircraft manufacturing [5]. The paper is structured in five sections. After the introduction, the current state of

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research is presented briefly in section 2. The integrated digital assistance system is described thoroughly in section 3, focusing on the individual elements as well as the resulting digitalised process. Also, the dynamic generation and utilisation of content for the system is described in detail. In section 4 the system is validated in a laboratory setting and the results are discussed with regards to the expected potentials, usability and scalability. Section 5 summarizes the results and closes the paper with an outlook.

2. Current state of research

2.1. Manual work

Manual work is flexible and can be used for operations of high complexity. However, it leads to variability and error prone processes by the nature of the human factor [1]. To reduce the error possibilities, workers have to thoroughly check work instructions which leads to a trade-off between productivity and quality. Handling these human factors in dynamic production environments is a complex challenge which is met by an abundance of technologies [3]. To efficiently leverage their potentials, manual work needs to be understood and operationalised.

Tietze [7] conceptualizes manual work using a generic work cycle. It consists of the phases information acquisition and processing *(1)*, acquisition of material and production aids *(2)*, product and workplace preparation *(3)*, execution *(4)* and follow-up *(5)*. Worker states are described by activity object combinations (e.g. ”setup” + ”tool” or ”view” + ”drawing”). Figure 1 illustrates the phases and the assignable activity object states (impossible states are displayed with a grey background). The possible states can be used for a comprehensive analysis of manual work, error causes and labour productivity. We use the activity object matrix to identify relevant work elements which can be supported or controlled by a digital assistance system and smart hand tools. Assistance of manual work can be evaluated by weighting the specific activity object elements in terms of their impact on productivity and quality. It should be noted that comprehensive digital assistance is only possible if all relevant activity object combinations across the generic work cycle are addressed. Each possible combination can either be *unaddressed* (white background), *supported* by indirect assistance (orange frame) or *controlled* by direct assistance (orange frame and background). Worker states that can additionally be controlled using an integrated digital assistance system (orange frame and blue background) emphasise the relevance of integration.

For instance, a digital assistance system can *control* the viewing of a drawing *(1)* by providing a CAD model and navigating to the area of the current task. The process of looking at a drawing is changed by controlling what the worker sees. Transporting materials to the workplace *(2)* on the other hand can be *supported* by clearly indicating the storage location in the application. The process of transporting the materials remains the same. A smart hand tool can *control* the setup of the tool *(3)* by assessing data on the equipped tool heads and issuing a warning in the event of incorrect equipment. It can further *control* the joining or cutting of the workpiece *(4)* by blocking the tool's operation when wrong process parameters are set. Finally it could *control* the writing of information in the drawing *(5)* by transmitting feedback data to a database. The processes are changed and digitally controlled in comparison to the use of conventional hand tools.

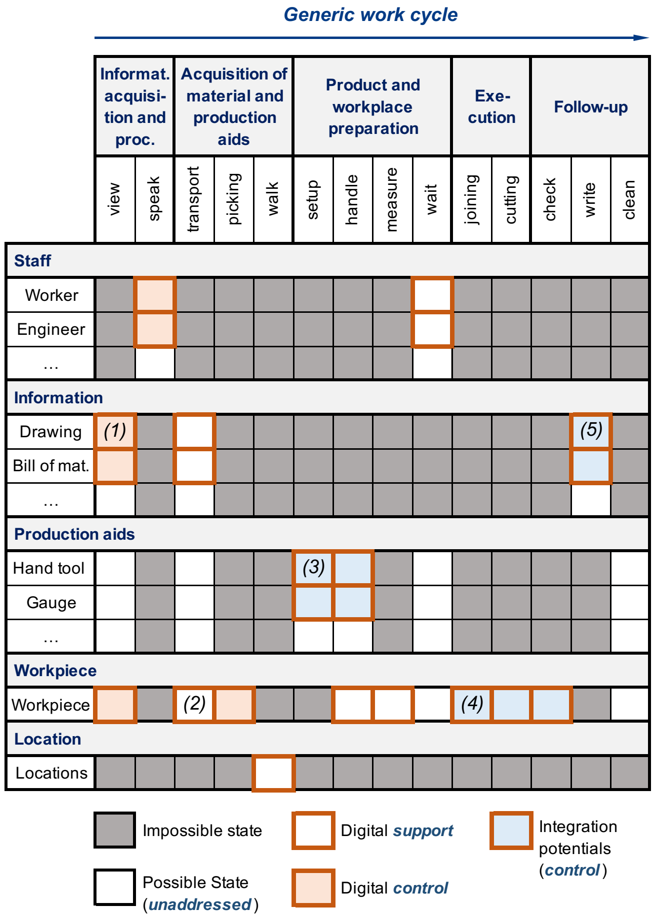

Fig. 1. Activity object matrix [7] with typical digital assistance and potentials

2.2. Digital assistance systems

Digital assistance systems leverage information and communication technologies that assist workers in their work cycle [8]. They receive and process information from databases and the environment in order to prepare it as usable output for workers and serve as an input source for feedback from the process [9]. Hinrichsen et al. [9] propose a morphology with various features to categorize digital assistance systems. These features include the type of system support (physical or informational), the scope of process support (partial or total process), the effort required for installation and reconfiguration at the workplace (low to substantial) or the type of context recognition (none, manual or via sensors). Most systems provide informational support for partial processes, rely on static contexts and require high efforts for installation and reconfiguration.

Halata [10] proposes an augmented reality (AR)-based assistance system that processes and visualises context-relevant information to support manual work in one-off production. Meluzov [8] also proposes an AR-based digital assistance system for maintaining products like compressors or ship engines. Both prototypes address specific areas in the generic work cycle and primarily provide informational support. Attention is paid to minimising the effort required to create the content and install the systems in the workplace. However, recognition of the production context is limited to manual input by the user. Rost [11] extends these systems by connecting various digital assistance systems via a central server to improve collaboration in one-off production. The connection enables updating the production context between the systems. However, the systems do not integrate any smart production equipment or sensors.

Tarallo [1] introduces an assistance system that combines a digital work document with a scanning system at the workplace. Work is supported by providing information, while the production context is updated by scanning the product's assembly progress. The system is set up statically and connected to one workstation. Jansen et al. [12] implement a more flexible assistance system to support maritime commissioning. The context specified in the digital application enables the integration of sensor data via measurement devices. Koch et al. [13] utilise smart inspection equipment to enhance digital applications in a similar matter. All three systems integrate sensor data to *support* process elements. However, they also lack the integration of smart hand tools that would allow to *control* further process elements and quality.

2.3. Smart hand tools

Smart hand tools can collect and transmit process data and receive and set process parameters via integrated sensors. Initial approaches to utilising these capabilities can be found in industry and research.

Umer et al. [14] implement an event-driven architecture that allows smart hand tools to send feedback data to a server and a visualization interface. Information about performed tightening is visualised and an initial check of the used torque is performed. However, the smart hand tools have no specific reference to the context of the process. The target torque values are entered into the interface as static parameters for the screw connections and must be adjusted in each case. Settimi et al. [15] provide workers with input using context-aware AR-glasses that assist through visual input when working with smart retrofitted tools. However, the system does not provide data transmission and setting of process parameters.

Hintze et al. [16] integrate a semi-automatic and smart drilling unit with a position sensor to enable dynamic context generation depending on the tool's position. Furthermore feedback data is thoroughly analysed for each drilling, using machine learning classification methods [17]. The system visualises the current tool position in a 2D view of the workpiece. The initial results are promising, however the developed system has high set up and content creation costs as it is developed for a static use case.

3. Integrated digital assistance system

3.1. Digital platform

A scalable internet of things (IoT) platform is utilised to integrate smart hand tools and digital assistance systems. The platform is based on the reference architecture defined by ISO/IEC 30141:2018 [18] and has been outlined in [19]. Figure 2 provides an overview of the platform elements that integrate both a creator application and an assistant application with smart hand tools.

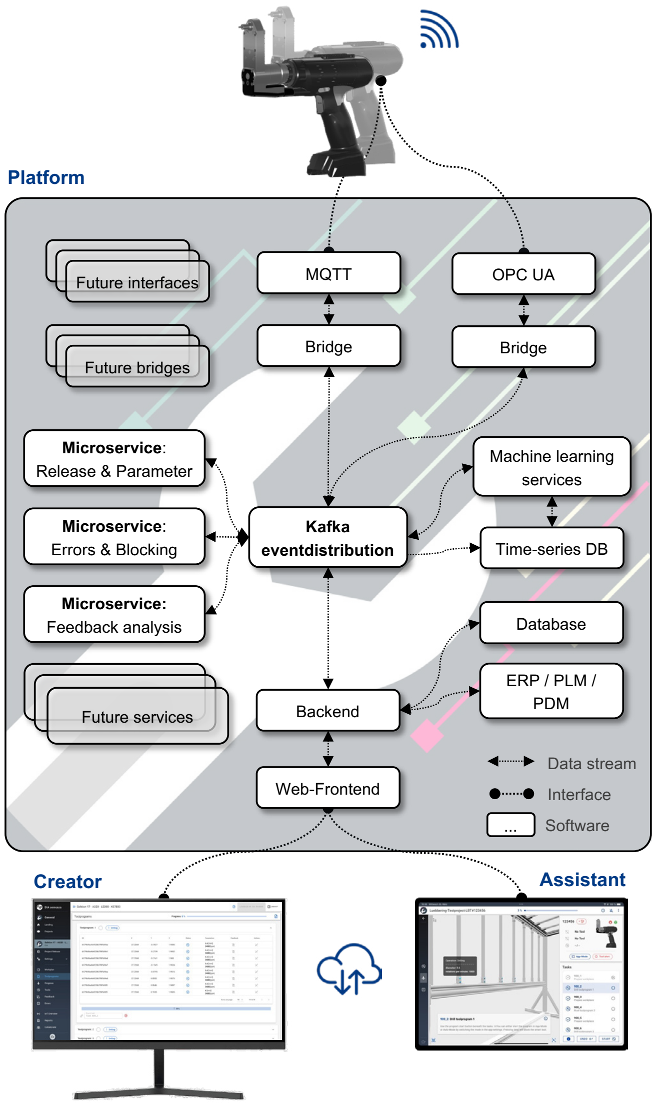

Fig. 2. Digital platform for the integrated digital assistance system

The platform uses container orchestration to host multiple software components and microservices with specific application purposes. The components are able to process data and transfer data packets between each other using different protocols. The smart hand tools can connect to the platform and its services using either the Message Queuing Telemetry Transport (MQTT) broker or the Open Platform Communications Unified Architecture (OPC UA) client. MQTT is used for latency critical data packets and OPC UA is used for data packets requiring standardised security features. Other protocols can be added to this gateway layer as required. To enable centralised processing of all data packets, each protocol is connected bi-directionally via a bridge to a central Apache Kafka broker.

If required, all data packets can be stored in a time-series database and may be analysed by machine learning services. In addition, various microservices are connected to the event distribution broker to enable autonomous control of the smart hand tools and software applications. For example, releasing and sending parameters or analysing feedback from a tool is handled in separate services. Each service can be replicated and hosted multiple times for scalability. This structure allows seamless integration of new features by adding microservices in the future.

The platform hosts two web-based applications that digitally support the creation of content (*Creator*) and the execution of manual work (*Assistant*). Both applications are provided by a core frontend and backend. The backend is connected to the Apache Kafka broker and serves as a bridge for data packets to the applications, as well as an interface to a document-oriented database and enterprise software for resource planning or product lifecycle and data management. The structure provides for the connection of process data, tools and applications to enable workers to effectively use the assistance system. The platform is scalable in both functionality and performance.

3.2. Digitalised process

The digitalised process is the target process that a work planner and a worker go through when using the software applications. It can be divided into four phases, each with different content and requirements for the digital assistance system. Similar to the generic work cycle, these phases do not necessarily have to be sequential or linear.

Content creation is the first phase. This is where the data for the digital assistance system is assembled and made available. This requires an abstract structure in the form of a data project that allows data to be assigned to the correct work process and tool. The features for creating the content should be easy to use and, if possible, allow the data to be created automatically. The content creation phase ends when a data project contains the required content and is released by the creator application.

General task processing is the phase in which the worker uses the digital assistant to perform manual tasks or tasks carried out with conventional hand tools. This includes tasks such as preparing the workspace or positioning components. In general, only context information about the work progress is required, as long as the software displays all the required information in a useful manner. For this purpose, a CAD model can be visualised in which all the relevant positions and components are highlighted. In addition, information about the work task and the production resources required can be visualised.

Smart task processing refers to all work contents that are carried out with a smart hand tool. The digital assistant should use the CAD model to visualise and parameterise the points at which the tools operate. Workers should then be able to work flexibly and accurately with the smart tools and software. The tools should automatically set correct process parameters depending on the current context, or be blocked if parameters are wrong and can not be automatically corrected (e.g. tool head diameter). All tool operations performed should update the database. For these functions, the production context must be dynamically updated. Finally, the status of the tools and progress should always be visible in the applications.

Documentation and follow-up describes the final steps of the process, where results and progress are documented. Documentation should be easily accomplished using the system and should be automatic for tool-related steps. In addition to documenting progress, the process parameters used should be recorded and the quality may be evaluated if possible. This requires a systematic decision as to which data is important and which is not.

3.3. Smart hand tools

The smart hand tools have a number of hardware features. In addition to the IoT-enabled machine body, the tool is equipped with an ultrasonic position sensor that indicates where the tool tip or point of interest (POI) is currently located within a 10 mm range. The tool uses a near field communication (NFC) and an inter-integrated circuit (I2C) interface to enable dynamic tool head replacement. The machine reads the currently equipped parameters from the NFC tag or the tool head data sent via the I2C interface. Figure 3 illustrates the components.

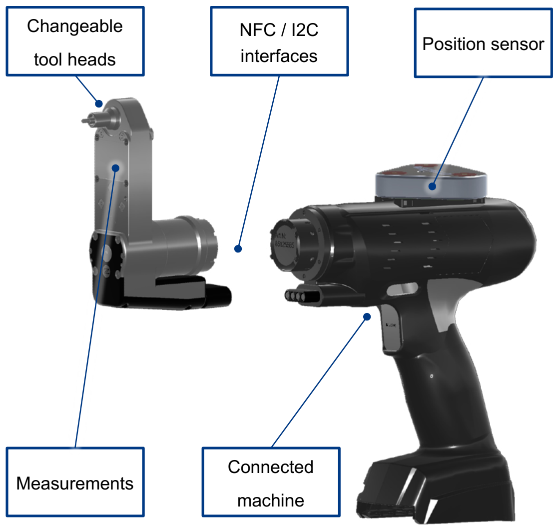

Fig. 3. Smart hand tool with changeable tool heads

The hardware components described enable various functions. The tool is connected to the IoT platform via an access point using either the MQTT or OPC UA protocol, allowing it to receive and process defined data packets related to the production context. It can further send data to the platform about the current tool status, the current location of the POI and the operations performed, resulting in four main functionalities.

Setting process parameters is the core functionality that enables context-relevant and smart task processing. The equipped tool head parameters are stored both in the NFC tag of the attachment and on the machine. When a new parameter data packet is received from the IoT platform, the tool overwrites the data both on the machine itself and on the tool head. It then adjusts the parameters on the hardware. This is, for example, the rotational speed when drilling or the torque when fastening. Furthermore, when a tool head is changed, the machine automatically adjusts its parameters to the parameters on the NFC tag.

Blocking and releasing is also accomplished sending and setting process data packets. However, this functionality is crucial for controlling the process quality for non-adjustable process parameters. By default the tool is blocked, which means that activating the trigger will have no effect. A data packet to release the tool is only transmitted when the tool is in the correct location with the correct process parameters set. If the tool moves out of the released area, it is automatically blocked again. This can, for example, prevent a hole from being drilled with a diameter that is too large.

Dynamic changing of tool heads enables a single machine to be used for a variety of operations. When a new tool head is inserted, the data is automatically read out via the NFC interface for drilling tool heads or the I2C interface for fastening tool heads. The data is transmitted to the microservices of the IoT platform and is then used to adjust the smart hand tool. The microservices can use the new data for the release process by updating the database and adjusting the position sensor's offset. This ensures that the new POI is positioned correctly in the individual tool tip. Currently the tool can perform drilling, reaming, and fastening operations through the use of different attachments.

Recording of measurement data is done in two different ways. When drilling, the machine records the motor current over time. For this purpose, an ampere value is read out every 100 ms and added to a feedback data packet. When fastening, the tool head records the incoming torque at the effective point with a frequency of 5 ms and also adds this to a feedback data packet. If a minimum operating time is exceeded and the operation is completed, the tool automatically sends the data packets to the IoT platform where it gets evaluated for process quality and anomalies that indicate potential problems like increased tool wear or a broken drill. The smart hand tool can additionally perform in-process control of the parameters. For example, a smart fastening process is available, where the tool reduces the rotation speed as measured values approach the target torque value set by the production context. This enables a more accurate process.

3.4. Digital creator

Content creation is assisted by the creator application to consolidate and provide data for the digital assistant. Releasing a data project for operation involves the following steps: creating a data project, developing a work plan, creating operation points for the smart hand tool (tool programs), and integrating a CAD model. Finally, the data project must be assigned to specific workers and smart tools before it can be released. The use case is entirely generic as long as these elements are present. Several software functions are provided for the convenient creation of this content.

After creating a data project with a unique identifier, such as an order number, the work planner receives an empty project with a guide to assist in creating the content. First, a CAD model of the product can be uploaded to the project. The creator application provides a converter, that can process different file formats. As a result, the CAD model is reduced in size and can be viewed with high performance. As a next step, the work tasks can be created either manually through input fields or by uploading an export from an enterprise resource planning system. Planners mark tasks as general or smart. Smart tasks receive a reference to which tool programs can be linked to.

Tool programs can be automatically generated by creating operation points from the CAD model using an algorithm. This is implemented for a use case in aircraft manufacturing. The algorithm checks the CAD model for fasteners such as screws or rivets. These elements specify the required target diameter. Process-specific rules are incorporated into the algorithm, which consider certain production standards (e.g. a particular material pairing requires specific drilling steps). Using these rules the algorithm then creates the necessary drilling steps as operation points with the necessary process parameters. Afterwards it creates the fastening steps as operation points and then consolidates the items into reasonable tool programs. The programs can then be assigned to the smart work tasks. A manual approach for creating these programs is also possible, but it will require significantly more time and effort.

After creating the work contents, the necessary resources must be added to the data project. This involves assigning users with roles, which are linked to specific authorisations in the digital assistant. Additionally, smart hand tools and required tool heads must be added. Finally, the data project can be released and then selected as a job in the digital assistant for the assigned users.

3.5. Digital assistant

The digital assistant supports the worker throughout the remaining process. To do so, the application allows the selection of data projects created, which opens the main view for operating. Figure 4 presents the application elements.

The main window displays the CAD model of the product, which can be interacted with using touch gestures and the provided buttons. The cube button, located in the lower left-hand corner, allows the user to navigate the view to the complete product. The lens button, situated in the lower right-hand corner, permits the user to navigate the view to the product element in relation to the current task. A product tree additionally allows for individual elements of the model to be shown, hidden, and navigated to. The overlaid information box provides context-relevant instructions to the worker. The task card on the right-hand side of the screen lists all tasks related to the data project in order of processing. The active task is highlighted with a blue

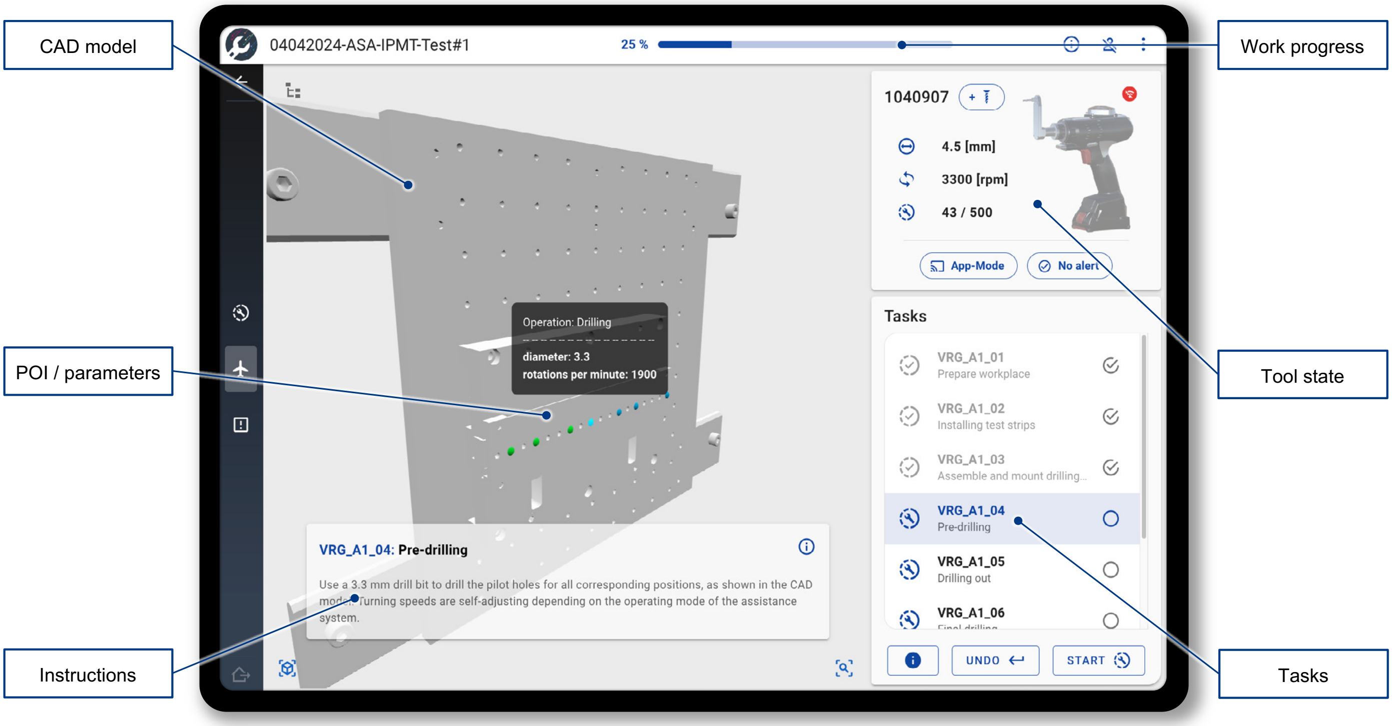

Fig. 4. Digital assistant for manual work with smart hand tools

background. Each item in the list is preceded by an icon on the left, which specifies the type of task (check symbol for general tasks and wrench symbol for smart tasks). The task identifier and title are displayed next. To the right, a check field indicates whether the task has been processed or not. If a task has been processed, the item is additionally greyed out. Work progress is dynamically calculated and visualised in the progress bar at the top of the screen. The tool card is located in the top right-hand corner of the overview and displays the current status of the smart hand tool. This includes the set process parameters, the equipped tool head, and information on the connection and release. Figure 5 illustrates some possible card states. The two chips at the bottom of the card indicate the operating mode of the digital assistant and whether an error has been identified in the smart hand tool. In the event of an error, an exclamation mark symbol can be selected in the left tab of the application to receive troubleshooting instructions. Additionally, a wrench symbol is provided, which offers an overview of the tools and tool heads included in the data projects as well as their set parameters.

General task processing is done using the instructions from the information box and the visualisation of the CAD model. The digital assistant autonomously displays and navigates to the relevant CAD elements. After completing the task, the worker marks it as done using a check button. This updates the database and progress bar, and the next task is automatically selected. The CAD viewer's field of vision and the contents of the information box are automatically adjusted accordingly. If the next task is a general one, the process restarts.

Smart task processing starts automatically if the active task involves the smart hand tool. This will cause the viewer to navigate to the tool program to be processed, displaying all the operation points as blue spheres in the CAD model. To process these points with the tool, the current production context must be determined. The digital assistant provides two operating modes for this: *application-controlled* and *position-controlled* context generation mode.

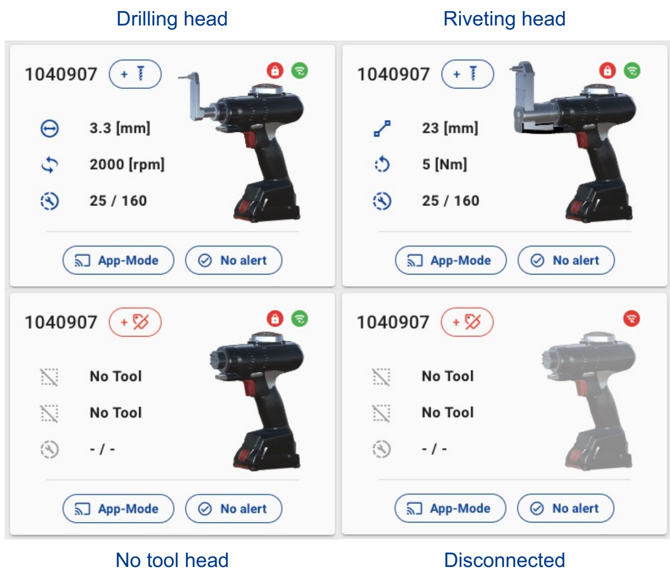

Fig. 5. Different tool states in the digital assistant

Using the *application-controlled* mode, the digital assistance system provides context in relation to the current work progress. When the start button is pressed, the next operation point to be processed begins to flash and a small overlay window appears above the sphere, which displays the required process parameters. At the same time, a data packet with these parameters is sent to the smart hand tool. This adjusts the parameters and sends a data packet back for confirmation, updating the parameters in the tool card. The worker then uses the CAD model to locate the operation point on the product and executes the operation. Once the action has been completed, the tool transmits the feedback data to the platform. The data is then verified, and the processed operation point is marked as complete. The sphere turns green, and the next process starts at the next operation point.

When using the *position-controlled* mode, the digital assistance system starts analysing the ultrasonic position data to provide context in relation to the tool's position. The operator can now position the tool at any operation point to be processed. As soon as the POI enters the tolerance range of a point, the sphere begins to flash and the parameter window is displayed as usual. The assistance system transmits the process parameters and the release data packet to the smart tool. Once the tool has processed the data, the operation can be carried out. Similarly to the application-controlled mode, the feedback data is processed and the sphere is set to green, initiating the next stage of the process. In contrast to the application-controlled mode, the processing sequence is not specified in the position-controlled mode. The worker is not constrained to a specific sequence and can utilise the CAD viewer to visualise the position of the POI for support.

In both operating modes, a warning window is displayed in the application as soon as a tool with incorrect non-adjustable parameters (e.g. incorrect drill diameter) attempts to process an operation point. The window shows the currently equipped tool head and provides information about the required tool head. After changing to the correct tool head, the dialog is automatically dismissed and the smart tool is released by the application. Once all the operation points of a tool program have been processed, the visualised spheres disappear and the associated smart task is automatically marked as complete. The digital assistant then proceeds to the next step.

Documentation and follow-up is facilitated by connecting a time-series database to the integrated digital assistance systems. This enables saving data packets while including their timestamps to allow planning and tracking of process optimizations in relation to the workflow. Additionally, all data packets sent by the smart hand tool are used to update the current status in the database. The tool's operations can be analysed further and documented regarding quality. A microservice on the IoT platform investigates the feedback data for anomalies that could indicate an irregular process sequence before updating the status of the point. A machine learning model is being developed to generate current-time or torque-time curves for various tool operations. This model aims to provide accurate information on the quality of the operation. If an anomaly is found, the operation point is colored red in the CAD viewer. The worker can then analyse the operation and manually reset the status and update the documentation if necessary.

4. Experimental validation

4.1. Experimental setup

For experimental validation, a mock-up of a shipbuilding assembly grid, commonly used for pipe assembly, is used as the basic test object. To enable different drilling steps to be performed, a drilling test rig has been developed that can be mounted on the mock-up. The drill stand itself can be placed in different positions on the rig. In another section of the grid, a metal plate with threaded holes of various sizes is mounted to test fastening operations. The position receiver for the ultrasonic position sensor is mounted on the ceiling and calibrated to the coordinate system of the mock-up. Additionally, a workstation is provided for manual tasks, and a rollable storage rule is available for the required production resources. Figure 6 shows a picture of the experimental setup.

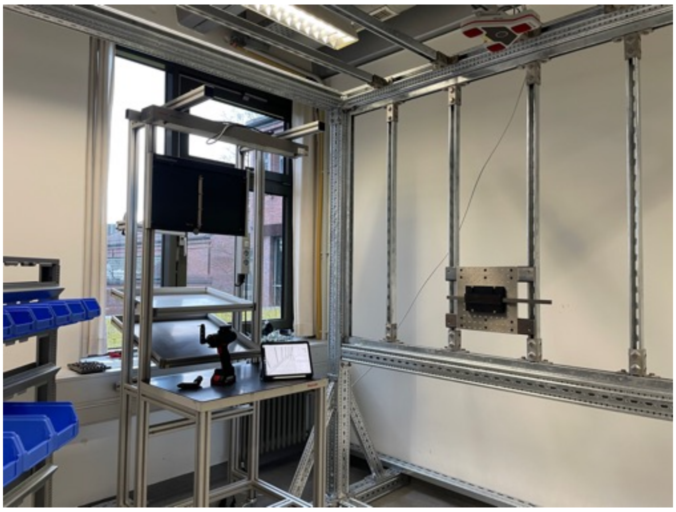

Fig. 6. Laboratory setup for validation

A standard process that consists of general processing and smart processing tasks is used for the validation. The process starts with mounting the drill stand on the rig at the position shown in the CAD model of the digital assistant. The stand is fed with two aluminium sheets to be drilled. The drilling template sets out the possible positions for each drilling operation. After the initial drilling, the template is removed to allow larger diameters to be drilled. The digital assistant is used in combination with the smart hand tool and four different drilling heads to carry out the operations. The stand is then removed and a number of subsequent operations are integrated into the process. Finally, the integrated digital assistance system is used to commission and fasten several screws with different torques and diameters.

Data from the smart tool's operations and position as well as a camera observation is used to validate the correctness and usability of the system. The experiment is performed by the developer and by an independent person to get an objective impression of the functionality.

4.2. Results

In general, the integrated assembly assistance system works as described and intended. During the tests, all necessary work tasks were completed and the correct tool feedback data was accurately documented at the appropriate operation points in the CAD model, both in the application-controlled and the position-controlled mode. The use of various levers, such as setting a minimum drilling time before sending feedback data ensures a smooth process. In the application-controlled mode, tool release and parameter setting are performed with very low latency as soon as the process is started via the digital assistant. The CAD visualisation effectively helps to find the correct operation point. The use of context generation based on the work progress means that errors cannot be completely ruled out, yet no incorrect tool operations were generated during the tests.

The position-controlled operation mode also functions as intended. Initially, there were some difficulties due to the small distances between operation points (approximately 15 mm), resulting in a high latency. This issue was resolved by improving the algorithm for releasing the smart hand tool. Any further discrepancies could be addressed by utilizing the option to undo the last action in the application. The basic functionality was successfully demonstrated. The combination of automatically navigating to the relevant view of the CAD model and the information provided in the information box enables effective task processing. In general, the integrated digital assistance system works very stable. The IoT platform deploys the applications with very high performance and the graphical user interface allows for clear processing of the individual work tasks.

4.3. Potentials

The integrated assembly assistance system harbours various potentials. The system promises to improve productivity by supporting preparatory, value-adding and follow-up activities through the provision of information by the digital assistant as well as the automatic parameterisation and documentation provided by the smart hand tool. This avoids uncertainties in process parameters and repeated checks of documentation. Furthermore, significant improvements in process quality can be expected, as the integrated system avoids incorrect processing by checking the parameters and linking them to the production context. This alleviates the conflict between high productivity and compliance with all quality requirements. Due to the flexibility of the system, the expected effects can range from individual production in private sectors to industrial mass production.

Additionally, potentials regarding digital content creation can be expected. Various work planner tasks can already be automated or reduced at present. In the future, it is conceivable that the CAD data can be linked with algorithms that generate assembly and disassembly tasks and create and assign tool programs for the smart hand tools autonomously. The resulting data sets can serve as content for the integrated system after being checked and adapted if necessary. This would also increase productivity in the indirect areas of production.

5. Summary and outlook

An integrated digital assistance system consisting of a creator application, a digital assistant application and a smart hand tool was developed and presented in detail. The functionality of the system was validated in a laboratory test and analysed with regard to its potentials.

The identified potentials need to be investigated further. The overall system is currently being tested in an ongoing study using the described laboratory setup. Using design of experiments methodology a test plan is drawn up for a larger number of test subjects. In the planned experiments a paper-based process with conventional hand tools will be compared with the application-controlled and position-controlled digitalised process. The hypothesised potentials in terms of productivity and quality improvement will be tested for significance. Furthermore, the general usability and acceptance are to be surveyed as a supplement to the technology acceptance in [5]. Qualitative interviews with workers in aircraft production as well as with workers from different fields in the German chamber of handcrafts will be carried out to investigate the usage of the system for large and highly standardised as well as small and changing products.

The integrated digital assistance system developed can be connected to further smart production aids or smart measuring equipment in the future. The modular structure of the interfaces and software modules allows scaling and further testing of the system and should be continuously expanded.

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