Balancing Care and Paperwork

Automatic Task Completion and Comprehensive Documentation in Care Processes

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Abstract. *Effort and quality of care documentation are among the most pressing challenges in the nursing domain due to demographic development and compliance demands. Hence approaches for decreasing the effort of documentation while increasing its quality are required. This work introduces the idea of automatic task completion and documentation which is achieved through a process-aware solution where physical objects utilized during care tasks are equipped with NFC tags. Nine use cases from the care domain are identified with domain experts and implemented through a proof-of-concept prototype. The time reduction of employing this technology is assessed by domain experts within the typical routines in a nursing home. The interviews indicate an average decrease in documentation time per shift of more than* 60%*. Inherently also documentation quality is increased as automatic documentation prevents forgetting to document certain steps or other errors. On top, this work fosters two ways for comprehensive documentation, i.e., log-based documentation for analysis and monitoring tasks and paper-based documentation as typically expected by nurses. The logs are automatically created and stored by the underlying process engine. It is shown how paper-based documentation can be automatically created based on process logs. Overall, this work provides the basis for automatic, comprehensive, and continuous documentation of care tasks based on NFC technology.*

Keywords. Business Process Ecosystem • Transformative Technologies • NFC • Automation • Care Domain

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1 Introduction

"Population ageing and demographic development tend to increase the demand for health care, social security and the care for the disabled and the elderly." (Burian et al. 2020). Although this development already forces nurses to spend less time on residents, at the same time, effort for documentation of the care work is not reduced or even increases. Besides the time effort of documentation an important concern is its quality (Jefferies et al. 2010). Documenting every interaction with a resident, from administering drugs to hydrating residents, is time-consuming and decreases the time spent with a resident. Additionally, the documentation is often conducted at the end of shifts, which leads to missing or even wrong entries as documentation is created from memory.

1.1 Problem Statement

Basically, documentation in the care domain is carried out based on paper-based or electronic health records where *"each have their drawbacks*

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in the real practice of nursing documentation" (Akhu-Zaheya et al. 2018). On the one side, paper-based documentation is found to *"not meet the requirements of high-quality documentation and communication among healthcare providers, because it is time-consuming, repetitive and inaccurate"* (Akhu-Zaheya et al. 2018). On the other side, the application of electronic health records is still limited and its impact on quality of documentation has not been fully proven yet (Akhu-Zaheya et al. 2018). As stated in (Lenz and Reichert 2007), (health) care in general craves for process-aware solutions. The process awareness leads to a task-oriented instead of data-centered view on the residents. This, in turn, facilitates the continuity of the documentation at the granularity of a care task and is hence promising for decreasing documentation effort and increasing documentation quality. Taking a process-aware care solution as a starting point, this work studies the following research questions.

1. *Automatic task completion*: Selected care tasks can be automatically completed by the process-aware care solution, i. e., without requiring user interaction. Typically, in a Process-Aware Information System (PAIS), users interact with the system through a work list where the active tasks are displayed and can be completed by the users. The goal of the envisioned process-aware care solution is to unburden the nurses from reminding clicking on the tasks in work lists by automatic completion. After the completion and according to the care process the next task is then automatically enacted (i. e., put into an active state, ready to be processed) by the system. The automatic task completion also furthers the automatic documentation (see *RQ*2) as whenever the system completes a task successfully, a corresponding event is stored in the process log.
   ↦ *RQ*1: *How to provide automatic completion support at any given care task*?

2. *Continuous and automatic documentation*: Documentation steps comprising all relevant care data are automatically conducted by the process-aware care solution when a care task is completed.
   ↦ *RQ*2: *How to provide automatic documentation support at any given care task*?

3. *Comprehensive documentation*: This question refers to the preparation and presentation of the care task documentation. As a process-aware solution is advocated, system-based documentation is achieved by logging. However, process logs cannot be used as format by nurses, hence, the solution requires a different, paper-based representation.
   ↦ *RQ*3: *How to enable the automatic generation of paper-based documentation based on process logs*?

4. *Reduction of effort and time*: The support by automatic task completion and documentation results in reduced time and effort for nurses.
   ↦ *RQ*4: *How effective is support of automatic task completion and documentation*?

1.2 Care scenario and contributions

*RQ*1 – *RQ*4 will be addressed based on process-aware care solution and the idea to elevate objects that are used during the execution of care tasks to IoT devices. We illustrate this based on the morning routine in a nursing home[1] as depicted by Fig. 1. The control flow is modeled using Business Process Modeling and Notation (BPMN). Process task *Change incontinence pants*, for example, is followed by subsequent task *Go to toilet with resident* whereas tasks *Give water* and *Give drugs* are ordered in parallel.

For each of these tasks, typically, the nurse has to document that i) the task has been completed and ii) data connected to the task (e. g., the task was conducted by Nurse A at time T with drug dosage D). A process-aware solution where care processes are modeled, enacted, and executed through a PAIS, provides essential support for automation

[1] The process is delineated by international nursing guidelines such as of the North American Nursing Diagnosis Association (NANDA) (Brooks and Massanari 1998) and national laws.

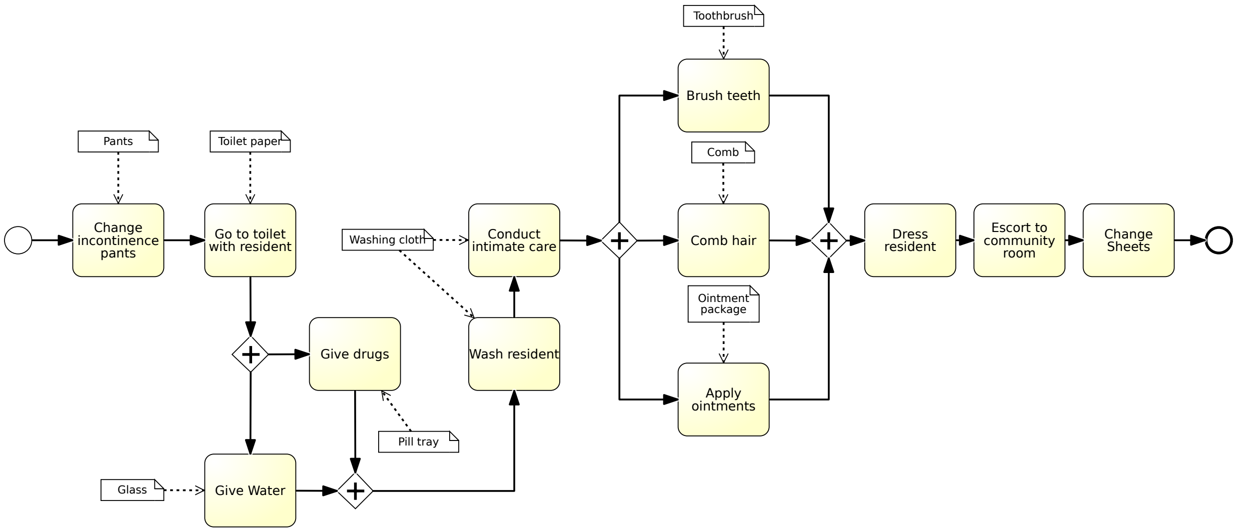


Figure 1: Daily morning care routine (BPMN notation using Signavio)

of i) and ii). More precisely, a PAIS offers work lists to the nurses. These work lists contain the care tasks that are due in their context (i. e., for a specific resident with his/her data necessary for the task). One example is task *Give drugs* where the dose for a specific resident is indicated in the work list. Hence, overall, PAIS support could already facilitates automatic and continuous care documentation.

However, we aim at going one step further, exploiting the fact that typically many tasks in a care processes utilize physical objects (denoted as *care utilities* in the following). Take the morning routine as an illustration,[2] Nine out of twelve care tasks involve care utilities, for example, *Pants* for task *Change incontinence pants*.

Care utilities are key to enable automatic completion of tasks, equipped with some set of data values. In detail, care utilities are equipped with NFC tags storing precise information about the care utility. Fig. 2 shows a resident bed equipped with an NFC reader in an experimental setting at the lab of the Research Group Workflow Systems and Technology and an NFC tag on the bottom right corner on a small plastic lid. NFC tags can be applied on nearly any surface, are small, and are cheap to be produced. Every time a care utility equipped with such an NFC tag gets swiped in front of the NFC reading device, a message is sent.

To realize this, tag readers are built into the nursing home residents' beds. Every tag reader is associated with the bed of one specific resident. Every time the reader detects a tag, it tries[3] to find a matching active task in the residents' care process, marks it as finished and documents the occurrence with a timestamp and the care utility. This can effectively reduce the time a nurse needs for the documentation of a resident and improve the quality of the documentation at the same time.

In order to design and implement the envisioned process-aware solution with all the required artifacts we apply the Design Science Research (DSR) methodology (Peffers et al. 2008). We consider DRS as suitable as *"DSR intends to generate design knowledge, that is, knowledge about innovative solutions to real-world problems"* (Brocke and Maedche 2019). At first, we elaborate requirements on the intended solution based on selected use cases from the care domain. These use cases are derived from interviews with experts in the

[2] As BPMN does not support the modeling of physical devices, we opted to model the care utilities as input data objects at the tasks where they are used.

[3] if no task is found, the activity for the resident is logged with a note that it was either an emergency or an error.

Figure 2: Resident bed equipped with NFC reader and an NFC tag on a small plastic lid.

care domain. The artifacts, in turn, are elaborated based on the requirements and evaluated through a prototypical implementation (feasibility) and interviews with domain experts (effectiveness). A summary of the acquired knowledge is presented in the conclusion based on a DSR matrix (Brocke and Maedche 2019). Note that this work is a revised and extended version of (Stertz et al. 2017). The extension includes a more comprehensive set of use cases, a more detailed and comprehensive solution design, and the automatic generation of paper-based documentation based on the logs.

The remainder of the paper is structured as follows: Sect. 2 provides background information on NFC technology together with justification to employ NFC technology in the envisioned process-aware care solution. The conceptual solution based on nine care use cases is presented in Sect. 3. Sect. 4 describes the architecture of a process-aware care solution and Sect. 5 presents its implementation and various design choices. The evaluation of the proposed solution is provided in Sect. 6. The initial solution has been designed and realized for the care domain. As discussed in Sect. 7 can be transferred to other application domains such as manufacturing and logistics. Related work is discussed in Sect. 8. Sect. 9 provides a summary and outlook to future work.

Overall, the results are promising. The evaluation indicates that automatic task completion and documentation can be widely applied in the care domain. Moreover, based on the assessment of the experts, the documentation time per nurse can be decreased by more than 60% on average.

2 Background on NFC technology

In order to tackle RQ1 and RQ2, particularly without disturbing nurses or residents, each care utility has to provide information about its existence and potentially its state. *Near Field Communication (NFC)* is one of the technologies for sending and receiving data wireless in close range. Alternative technologies would be Barcodes or RFID. In the following, pros and cons of the three technologies are discussed.

Barcodes: 1D barcodes store rather little information (13 digits) since usually additional information is then looked up in the database (Kato and Tan 2005). 2D barcodes, e. g., QR-Codes, can hold more information which can be decoded without accessing a database. Limitations of using barcodes are restricted usage ("line of sight" is needed), lack of reusability (barcodes are printed on the object), and that they cannot be edited.

Radio-frequency identification technology, RFID (Want 2006) supports active and passive devices. Another advantage is that no "line of sight" is required. Moreover, RFID devices are cheap to produce, hence can be used at a large scale from an expenses point of view.

Near Field Communication, NFC (Agrawal and Bhuraria 2012) is used in many applications and devices such as Smartphones, Debit cards, and tickets for public transportation. NFC builds upon the RFID technology (Agrawal and Bhuraria 2012) and communicates on a very short range below $10cm$. NFC can work with an active device, the NFC reader, and a passive object, like a tag or card. The reader can write and read information of the object. A big difference to RFID is the range. A RFID reader can create a larger electromagnetic field to automatically detect different objects going through it. Since the communication range of the NFC reader is quite low in comparison, there will not be any unwanted detection of different tags entering a room, which would create a flawed documentation. NFC tags are cheap to produce, very thin, and can be attached to any surface, like stickers.

In conclusion, NFC is chosen for the process-aware care solution presented in this work due to the following advantages:

1. *Ubiquitous availability:* NFC-capable devices can be found everywhere nowadays such as smart phones, toys, table computers, and even watches. This allows for an approach which is feasible to acquire and relatively easy to learn, since the devices are used in everyday lives.

2. *Better security:* Since the distance to communicate is only about a few centimeters, NFC is safer to use than RFID. The short range increases the level of difficulty to create unwanted detections and or malfunctioned detections.

3. *No unwanted detection:* Another advantage of the close communication range of the NFC technology is the elimination of unwanted tag detection. In a room of a resident are many care utilities. RFID creates a large field, where every tag will be detected. This is useful for warehouses, but in the nursing home we only want to detect the right NFC tag at the right time. The short communication range allows only one tag to be detected if it is right in front of the NFC reading device, thus allowing for a correct documentation.

4. *Usability:* Existing approaches state that *"NFC technology was perceived as very intuitive and the information quality of each patient's health status could be improved"* for a project on documentation of the health status of patients (Prinz et al. 2012). Another approach utilizes NFC in nurse training, emphasizing the unobtrusiveness of the solution (Fontecha et al. 2011). For not changing the daily routine of nurses too much, a way to unobtrusively register these tags with a PAIS during care activities is needed. Reading the tags is not intended to take longer than a few seconds and should happen right at the moment the care task is finished. Additionally, nurses are generally open to try out new technology as long as it helps reducing the documentary effort (Doran et al. 2010).

3 Conceptual solution design based on use cases

The solution design covers nine use cases that are relevant for automatic task completion and documentation in care processes.

Fig. 3, gives a quick overview of the use cases, their actors and the relations between the use cases. Organizational tasks such as "Register resident" are usually conducted by the administrative staff of a nursing home. If the nursing home is small, care staff members can do organizational tasks as well. Use cases like "Write Utility Information" is a use case for more complex care utilities, which provide information on contradicting care utilities, for example two drugs that act as a blood thinner are contradicting each other, since the doubled amount of blood thinners will lead to complications. A detailed description of all use cases is following.

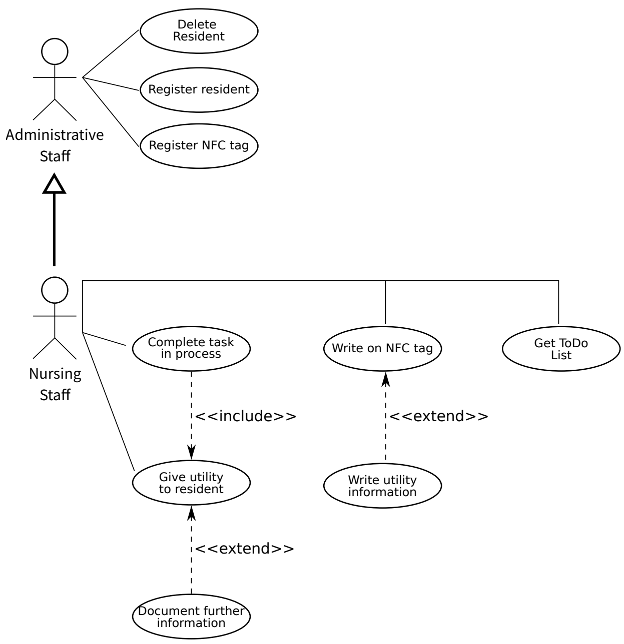


Figure 3: Use case Diagram showing the potential actors and use cases

A use case description contains information about its *scope*, *level*, *primary actor*, *stakeholders and interests*, *preconditions*, *postconditions*, *realization* and *frequency of occurrence*. The *scope* of all relevant use cases is *system-wide*, i. e., the related information is relevant and visible not only for a certain task, but throughout the system. The *level* for all use cases is *user goal*, i. e., all use cases can be done completely by one staff member or nurse at one time, thus keeping the data consistent.

For each task that employs NFC-supported documentation, first of all, a corresponding NFC tag is registered in order to be used in the sequel (cf. Use case 1). Also, each resident has to be registered in the database (cf. Use case 2). Each resident is associated with one NFC reader attached to a bed, and each NFC reader is associated to at most one resident. This one-to-one relationship between residents and NFC tags is necessary for the assignment of events to the resident.

It is also possible to write on an NFC tag (cf. Use case 3), specifically, the type of the connected care utility (e. g., a comb). The type can be *simple* or *complex*. For complex care utilities the NFC tag holds additional information, e. g., the dosage for utility drug. In the realization of the use case this distinction is made by invoking a subprocess.

If a care utility contains complex information this information is written onto the NFC tag as described in Use case 4. An example is painkiller Parkemed as care utility which can be administered in dosages $250mg$ and $500mg$. Dosage is a critical parameter in the context of care utilities due to the prevention of misuse. Use case 4 can be generalized to other parameters. Nested information can be stored on an NFC tag as well, i. e., using containers. Containers also enable to store the information of more than one care utility on the NFC tag. The medical containers are usually prepared in the nursing room during quieter times like the night shift. To write the information on an NFC tag, a tablet in the nursing room is required. Tablet PCs can act as NFC reading and writing devices.

Often staff members want to retrieve the upcoming tasks, either for themselves or for a specific resident. Both can be initialized by reading the NFC tag assigned to the staff member or the resident respectively. As process technology is employed the upcoming tasks can be determined based on the to do list for the staff member or resident (cf. Use case 5). Knowing upcoming tasks, the staff member can optimize the personal work routine and hence avoid unnecessary tasks or waiting times during his or her shift. A requirement for the accessing the to do list is that the

Table 1: Use case: Register NFC tag

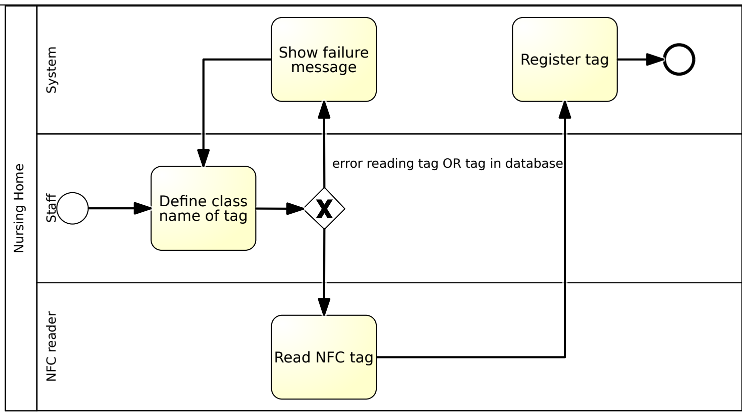
primary actor	staff of nursing home
stakeholders and interests	staff member (stakeholder 1) wants to register an NFC tag for documentation.
preconditions	ID of NFC tag not in database (see *realization*)
postconditions	unique ID for NFC tag in database (see *realization*)
realization	
frequency	often

Table 2: Use case: Register resident

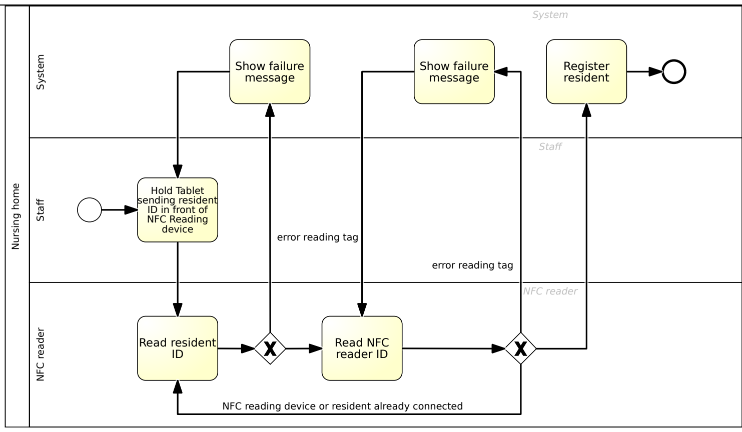
primary actor	staff of nursing home
stakeholders and interests	staff member (stakeholder 1) wants to register a resident and relate him or her an NFC reading device.
preconditions	new resident has not been assigned an NFC reading device (see *realization*)
postconditions	NFC reading device is connected to the resident in the database (see *realization*)
realization	
frequency	often

Table 3: Use case: Write on NFC tag

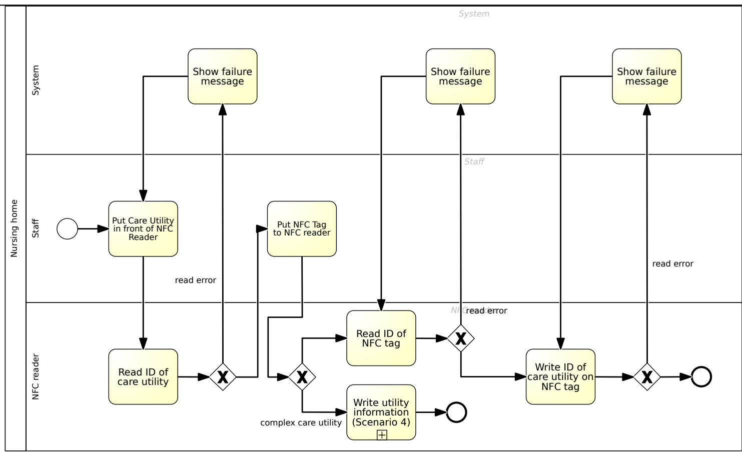
primary actor	care staff
stakeholders and interests	staff member (stakeholder 1) wants to connect a care utility to a specific NFC tag.
preconditions	NFC tag is not connected to a care utility in the database yet (see *realization*)
postconditions	ID of NFC tag is connected to a care utility in the database (see *realization*)
realization	
frequency	often

Table 4: Use case: Write utility information

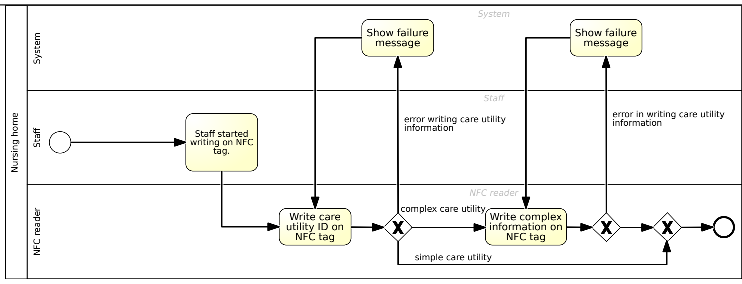
primary actor	care staff
stakeholders and interests	staff member (stakeholder 1) wants to connect a care utility to a specific NFC tag.
preconditions	utility type is complex; complex parameters (like dosage) need to be specified (see *realization*)
postconditions	dosage is written on NFC tag with ID of care utility (see *realization*)
realization	
frequency	often

Table 5: *Use case: Get ToDo list*

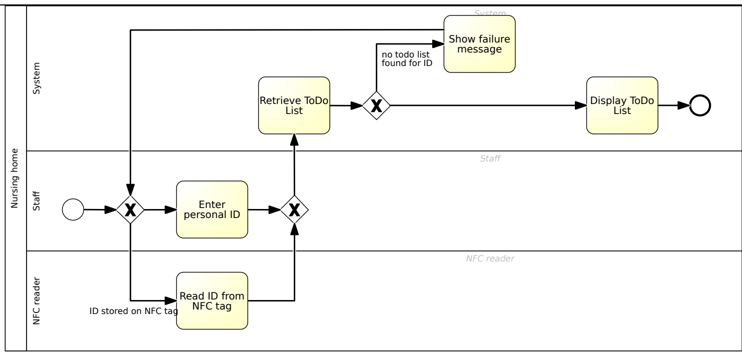
primary actor	care staff
stakeholders and interests	staff member (stakeholder 1) wants to avoid unnecessary tasks and waiting periods during shifts.
preconditions	–
postconditions	list of upcoming tasks is received (see *realization*)
realization	
frequency	often

Table 6: *Use case: Give utility to resident*

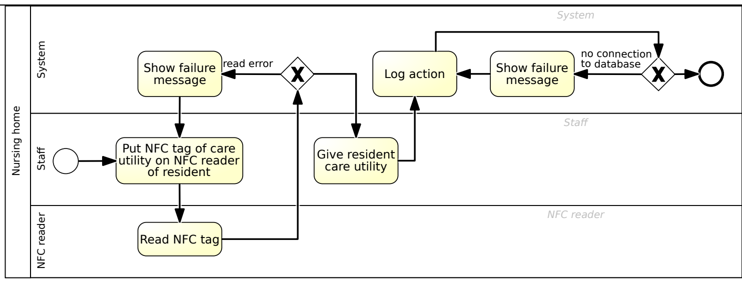
primary actor	care staff
stakeholders and interests	staff member (stakeholder 1) wants automatic documentation of care utility given to resident.
preconditions	resident is ready to receive care utility; NFC reading device for resident is registered; NFC tag of care utility is registered and has necessary information stored (e. g., dosage)
postconditions	resident successfully receives care utility; this is documented automatically in the system (see *realization*)
realization	
frequency	often

Table 7: Use case: Document further information

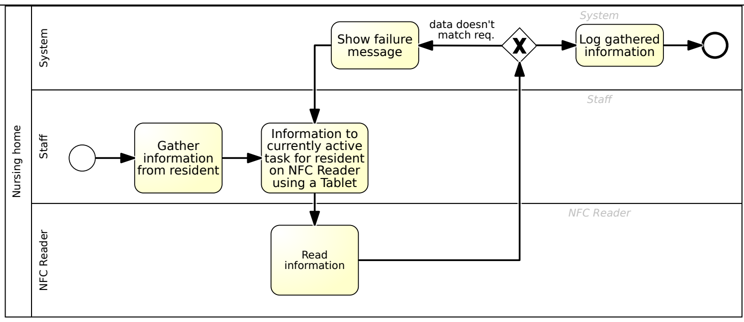
primary actor	care staff
stakeholders and interests	staff member (stakeholder 1) wants to document further information, e. g., the health status of a resident.
preconditions	additional information cannot be stored on NFC tag
postconditions	additional information is (correctly) stored in database (see *realization*)
realization	
frequency	often

Table 8: Use case: Document injected task

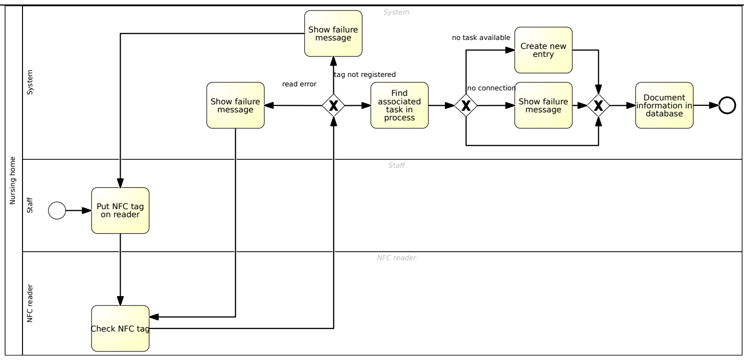
primary actor	care staff
stakeholders and interests	staff member (stakeholder 1) wants to document his/her completed duties; nursing homes (potential stakeholder 2) wants documentation of higher quality
preconditions	NFC tag registered; NFC tag stores information; resident is registered
postconditions	task completion is stored in database (see *realization*)
realization	
frequency	rarely

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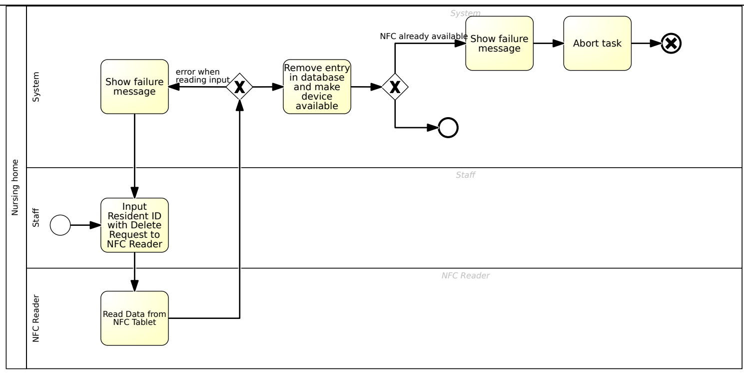
Table 9: Use case: Delete resident

primary actor	staff of nursing home
stakeholders and interests	staff member (stakeholder 1) wants to maintain a current status in the database and to create room for new connections
preconditions	resident leaves nursing home; resident still connected to NFC reader
postconditions	NFC reader is disconnected and available for new connection (see *realization*)
realization	
frequency	rarely

staff member is equipped with a tablet computer holding an NFC reading device, which displays the currently active tasks.

Use case 6 *Give Utility to Resident* realizes the automatic documentation of a care task. The care utility carries an NFC tag which is placed on the NFC reading device of the resident. Doing so the connection between resident (specifying the treatment process instances) and care utility (specifying the care task) is made. The NFC reader decodes the information read from the NFC tag. The system automatically documents that the care task has been completed for the resident with all necessary information such as timestamp and possibly dosage. Looking at the morning care shown in Fig. 1 together with care utilities, the automatic documentation would be conducted, for example, when the staff member hands the toothbrush to resident *Smith*. The system would then automatically document that task *Brush teeth* has been completed for process instance *Smith*.

For some tasks the automatic documentation that the task was completed using the care utility is not sufficient, e. g., if further relevant information is created and to be documented as well. An example is a discussion about the health status of a resident between staff member and resident. Use case 7 summarizes the necessary steps, i. e., the documentation of the additional information by the staff member using a form which is stored in the system.

Use case 8 offers the option to document information connected to an NFC tag that is not assigned to any task. In this case, a task is injected and all information is documented in the database by the system.

Use case 9 describes the process if a resident leaves the nursing home and the connected NFC reading device (individual to this resident) is disconnected from the resident. The latter is realized by removing the associated entry in the database. Afterwards the NFC reading device can be reused, i. e., made available for a new resident.

4 Realizing automatic task completion in a process-aware care solution

The goal of this section is to show how automatic NFC-based task completion and documentation can be realized in a process-aware care solution.

4.1 Architecture

The process-aware care solution *ACaPlan*[4] has been developed for supporting the development and execution of flexible care processes based on established care guidelines, i. e., Nursing Interventions Classification (NIC), Nursing Outcomes Classification (NOC), and NANDA (Kaes et al. 2015). *ACaPlan* builds on the multi-purpose cloud process execution engine CPEE[5] (Mangler and Rinderle-Ma 2014). The user interface is realized through the *Who Cares* cockpit. Fig. 5 depicts these existing components in black. In order to enable NFC-based task completion the existing solution is extended by the newly realized components depicted with red, dotted outlines, i. e., (*Automatic Care Completion* (*ACC*), *NFC Reader*, *XES Logging*, the data repositories, and optionally a *KPI Monitor*.

In order to derive a suitable set of components, the use cases presented in Sect. 3 have been analyzed for required common functionalities as well as data artefacts. This includes interaction with components and data artefacts, that are available through ACaPlan and the Process Engine we use. The results of this analysis are depicted in Fig. 4.

As can be seen in Fig. 4, each use case requires a set of functionalities and data artefacts. For example, in Use case 2, when a simple care utility is registered, the *Hardware* identification (tag id) has to be connected to an entry in the *Care Utilities* table. This also requires the *NFC Reader* component to scan the tag. In Use case 3 basically the same is done, except that more complex semantic information like side effects has to be saved. Also, for example for a pill tray, an individual NFC tag has to store dosage. The schema for the data that has to be stored on the NFC tag has to be saved in the care utilities data repository as well.

The granularity of individual components becomes clearer with each scenario. NFC Reader and Hardware, although present in all scenarios, are separate, because *NFC Reader* represents functionality, whereas *Hardware* constitutes a data artefact.

The necessity for the *ACC* components stems from the necessity to coordinate the information flow between different components when utilized from a process engine (see Fig. 6).

The final architecture is depicted in Fig. 5. Components for implementing the ideas in this paper are modeled with dotted outlines (red). All other components (black) are part of the existing solution we built our implementation on.

In the following, the general functionality of the newly realized components from an architectural point of view is described. Design choices and implementation details, in particular the new log format, are presented in Sect. 5. At the end of this section the realization of the scenario "Give utility to resident" (cf. Tab. 6) illustrates the interaction between the components of the system.

4.2 The basis – Automatic Care Completion

Automatic Care Completion (ACC) as the main component has the following functionalities:

- *Collection of events from the process engine implementing the therapy processes.* ACC knows all currently active tasks for all residents.
- *Collection of events from the NFC readers.* ACC knows all care utilities and the properties that have been used for each resident.
- *Completion of active tasks.* ACC selects all tasks that are potentially affected by a care utility and supplies it with information found on the NFC tag and allows the process engine to finish this task. Alternatively, it notifies the caretaker that additional (manual) input is necessary. We envision that in future revisions of the system,

[4] Adaptive Care Planning
[5] http://cpee.org/

	Process Engine	ACC	NFC Reader	Hardware	Care Utilities	XES Logging	Patient Data	ACaPlan (e.g. TODO List)
Use case 1			X	X				
Use case 2			X	X			X	
Use case 3			X	X	X			
Use case 4			X	X	X			
Use case 5			X	X			X	X
Use case 6		X	X	X	X		X	
Use case 7		X	X	X			X	X
Use case 8	X	X	X	X	X	X	X	X
Use case 9			X	X			X	

Figure 4: Use case analysis: derivation of components and data artefacts

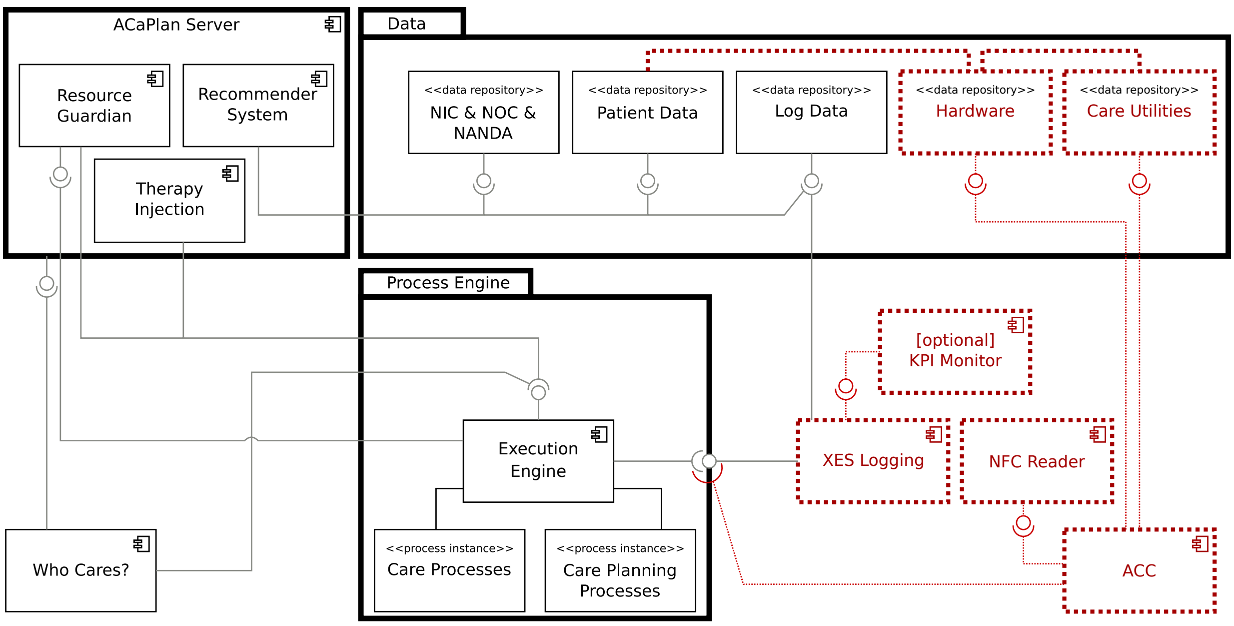


Figure 5: Architecture for process-based care system with embedded NFC-based documentation. Red-dotted components have been developed in this work.

caretakers are prompted to record voice messages which are automatically assigned to the correct task.

4.3 Data repositories: hardware & care utilities

In the hardware repository, all residents are stored with the ID of the related NFC reading device which is a prerequisite to relate events and residents.

The care utilities repository contains all data about the care utilities used during treatment, i. e., care utilities and their encoding, their type (simple or complex), interrelations with other care utilities such as side effects of drugs, and defined breaks between using the utilities (mainly relevant for drugs again).

Therapy processes often contain tasks that are executed in parallel. A resident, for example, has to be medicated and at the same time a proper level of hydration (periodic liquid intake) has to be maintained. While assigning the intake of a certain drug to a task might be unambiguous, proper hydration might be a side effect of different tasks such as serving the resident a cup of coffee or a glass of lemonade with the lunch, as well as the glass of water that is part of the medication intake all count towards the goal of proper hydration.

When hydration is seen as task in the therapy process that (in a loop) collects the quantities of liquid that has been consumed over the course of a certain time period, it becomes clear that whenever one of the above (separate) tasks happen, the hydration task additionally has to be provided with the correct information.

Thus, the care utility repository does not merely contain a list of data, but a flexible ontology that contains all facts connected to a certain care utility. Based on the ontology it becomes possible to identify the correct hydration task from a multitude of care utility applications. All facts in the ontology are described as turtle triplets and can be queried through SPARQL (Prud'Hommeaux, Seaborne, et al. 2008).

4.4 Interaction Between the Components Based on a Scenario

As an example the implementation of the scenario conceptually described in Scenario 6 is provided. This scenario is chosen, because it covers a wide variety of interactions between ACC, nurses, residents, care utilities, and NFC reading devices (i. e. a full-stack example). In order to register the usage of a care utility (stored in "*«data repository» Care Utilities*"), the NFC tag attached to the utility has to be moved near the NFC reader.

In the "*«data repository» Hardware*" the IDs of the NFC readers for all residents are stored (thus the connection to the existing "*«data repository» Patient Data*").

The component "*NFC Reader*" sends a stream of events to the "*ACC*" component, whenever care utilities are used with NFC readers.

The "*ACC*" utilizes the data repositories to interact with the "*Process Engine*" regarding the process execution. It is assumed that using a care utility always correlates to a currently active care task in the process engine. Every other situation is a possible violation of care standards.

However, the usage of care utilities also has a semantic side to it, that is not easily covered by imperative process models and their strict logic. For example, the glass of water coming with medication contributes to hydration (i. e., contribution to multiple tasks), or medication may have side-effects when given with other medication (i. e., detect problems in process logic). Of course, the process logic describing the care of a resident could encompass all fuzzy uses and side effects, but that would complicate the process model to a point where it would be hard to maintain by nurses.

Thus the "*«data repository» Care Utilities*" includes an ontology which is used by the "*ACC*" to generate warnings and identify the relevant active tasks. Finally, for complex care utilities the events include information such as dosage and time interval (e. g., for administering drugs) which again can be utilized to issue warnings and check compliance to care standards.

If "*ACC*" successfully identifies a care task, the data of the NFC tag (e. g. dosage information) will be sent to the process engine, and the event will discarded (events are treated as a stream). The activity is then marked finished in the process engine, which in turn results in a log entry in the "*Logging*" component, and the next task will be marked as active. If "*ACC*" does not find a correlating care task, something not foreseen in the process happened. The "*ACC*" then registers the occurrence with the "*XES Logging*", the progress of the care process remains unchanged. XES[6] is usually serialized in an XML document, which is human and machine readable. Also, the XES standard allows for a plethora of algorithms focusing on the discovery, conformance checking and enhancement of processes, known as process mining (Aalst 2016).

The "*XES Logging*" component stores data as XML, containing timestamps of the events, the ID of a care utility with the described details, like inhibitors, suggestions and dosage, as well as notes and additional input from the caretakers. Additionally, it provides data to any interested external services, such as an optional "*KPI Monitor*" component.

5 Design choices and implementation details

In order to realize and complete the solution design, a prototypical implementation supporting the scenarios presented in Sect. 3 is required. This section describes the design choices and implementation details in more detail (cmp. Fig. 5):

- Using ACaPlan and CPEE as the basic software stack.
- Using NFC on the hardware side.
- Using XES for logging.
- Process XES documents and KPIs.

[6] eXtensible Event Stream, http://www.xes-standard.org/

5.1 ACaPlan & CPEE

The implementation extends an existing solution called Adaptive Care Planning (ACaPlan) (Kaes et al. 2015) that realizes therapy processes for nursing home. We selected ACaPlan, because to the best of our knowledge it is the only solution in the domain that (a) has a modern message-based architecture and (b) is readily available as open source. ACaPlan provides a system, where a resident in a nursery is related to a therapy process. ACaPlan uses medical knowledge (derived from literature) which is stored in the "*«data repository» NIC & NOC & NANDA*". A graphical user interface (*Who Cares*) to create and modify care processes for residents from this repository allows for simple exploration of examples and scenarios.

Our implementation also utilizes event streams from the CPEE. The CPEE relies on a publish/-subscribe model for a wide variety of events that occur during process execution. For the purpose of this paper we rely on notifications whenever a task becomes active or is finished (per process, i. e., per resident). The currently active tasks are compared to the events of by the "*NFC Reader*" component to determine which task (or which tasks) a certain care utility tackles.

It is important to note that the interaction with the Process Engine, ACaPlan, and concepts presented in this paper is generic. Thus, the CPEE used by ACaPlan could be replaced by other process engines, e. g., Apache ODE.

5.2 NFC

Background information on NFC is provided in Sect. 2. At the design level, whenever an NFC reader sends information about a care utility, with the help of the data repositories as depicted in Fig. 5 the following information can be deduced:

- Which resident is affected and thus: which care process is affected?
- What additional information about this care utility is available?

In order to make the functionality available, we developed an open-source C library which talks to the NFC hardware[7] via a hardware-supported binary communications protocol

This C library serves as a basis for high-level languages bindings. We actively maintain an open-source ruby binding.[8]

5.3 Interaction of Components

To give a more detailed view on this architecture, the sequence diagram in Fig. 6, shows the interaction of the new components in the system and how the execution engine gathers the data from the hardware repositories.

Fig. 6 also explains how the ontology in the care utilities repository is working. For example, if the current active task asks for hydration and a glass of water is detected, a SPARQL query is used to understand the concepts of a glass of water and to see if the concepts of a class of water are actually a part of hydration care utilities.

6 Practical evaluation

The evaluation is divided into two parts. At first, the reduction of documentation time and effort by automatic NFC-based task completion is evaluated with domain experts. Secondly, the feasibility of the creation of paper-based documentation from the XES logs is shown.

6.1 Reduction of documentation time and effort

The evaluation with domain experts is described based on its context, the data collection procedure, and the obtained results.

6.1.1 Evaluation context

The evaluation context is set by two different nursing homes. The daily routines in these nursing homes can be divided in morning routine, lunch, and afternoon & evening routine. Lunch mainly consists of two tasks, i. e., assist residents with intake and give drugs. For the intake a form has to be filled manually for documentation. Support for this documentation task has been outside the scope of this work so far. Giving drugs is supported by the system. All of the process models have been modelled with experts from the nursing domain, specifically from the 2 nursing homes.

Morning routine

The process model for the morning routine is depicted in Fig. 1 together with the assigned care utilities. One nurse is typically responsible for 14 residents. The morning shift for a nurse starts at 7:30 am and he/she has to conduct the morning routine all by himself/herself within 2 hours. Afterwards a second nurse joins. The tasks for the residents are split evenly. The residents have different levels of care, i. e., are able to conduct a varying number of tasks in the morning routine themselves. Even though the independence of the residents is to be preserved as much as possible, each of the tasks has to be documented by the nurse. This results in a higher amount of time for residents with a low level of care. As there is a substantial time pressure to finish the morning routine for all residents before breakfast, often the documentation of the morning routine is postponed to the end of the shift from noon to 13:00 pm. This constitutes a risk of lowering the documentation quality (e. g., by forgetting tasks).

Evening and Night Routine

Fig. 7 depicts the evening and night routine. For this shift a nurse is typically responsible for about 70 residents. During the night, additionally, a graduate nurse is present for emergency cases. The night shift runs from 8 pm to 7:30 am the next day. After handover of shift the general health status and clothes are checked. Repeating tasks of the night routine are changing incontinence pants and bed positions of the residents in order to avoid bedsore, typically performed every 2 to 3 hours. In quieter periods in between documentation is performed. In case of emergencies the nurse prepares the associated documents and calls the ambulance if necessary.

[7] http://www.kronegger.com/
[8] https://rubygems.org/gems/nfclib

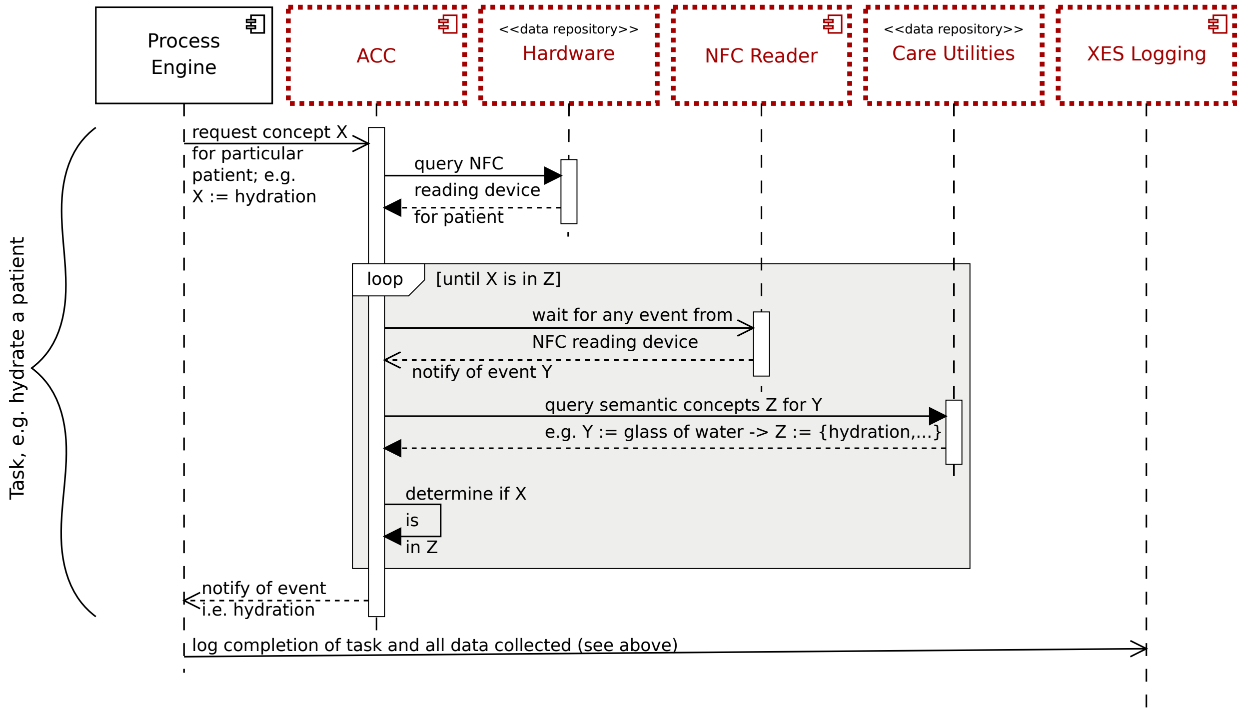


Figure 6: The communication of the components.

6.1.2 Data collection procedure

The evaluation is based on two expert interviews with nurses from two different nursing homes. In the beginning the nurses were asked to describe the tasks that have to be done with every resident of the nursing home. This lead to the process models, which can be seen in Fig. 1 and 7. Afterwards data has been collected on the average time spent on the documentation for each shift and when this documentation is typically done by asking them to log their behavior for one week. At last, the nurses where asked, for each shift and for each task, how much time could be saved with the solution presented in this paper, taking into account that some tasks need additional information (i. e. comments by the nurses) that can not be automatically acquired. Thus, the nurses, for each shift and each task, provided the following information:

- Potential physical objects and how practical it would be to use them for automatic logging.
- Current documentation effort, and estimated savings with the solution presented in this paper.

The time for using a physical care object is determined by three aspects:

- How long is the physical object used for the care purpose?
- How long does it take to bring the physical object next to an NFC reader (integrated into the bed)?
- How long has the physical object to remain next to an NFC reader, in order for the data to be read out?

While the duration of the first aspect is fixed, the two other aspects replace the manual documentation. They are assumed to take about 10 seconds in total per task.[9]

[9] It took about 2 seconds in tests with nurses, but we conservatively estimated 10 seconds to account for delays due to sloppy usage

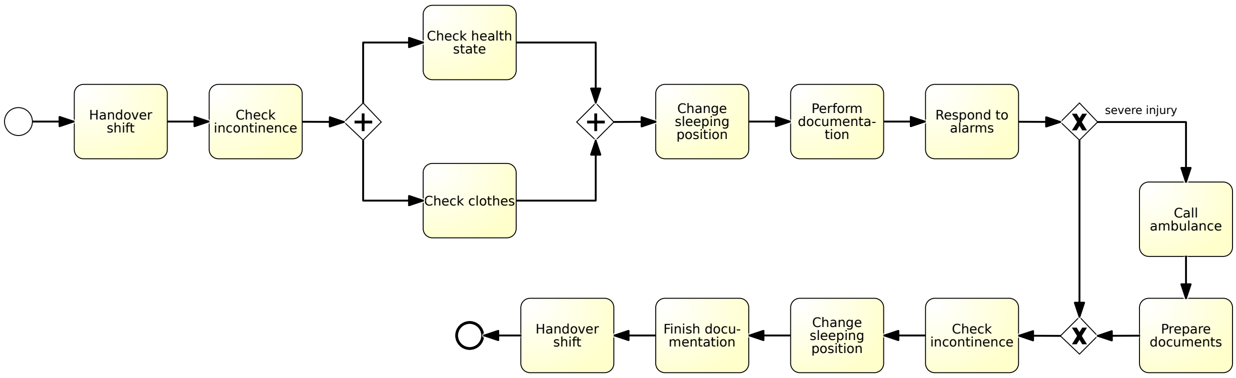


Figure 7: Process Model for Afternoon / Evening Routine

Additionally to the expert interviews, the whole system has been prototypically implemented in our lab of the research group. As can be seen in Fig. 2, a testing environment using nursing home beds and NFC reading devices has been built and the individual tasks have been replayed in the testing environment.

6.1.3 Obtained results

Tab. 10 summarizes the results of the study which are explained in more detail in the following. The overall time reduction as expected by the experts are about 60%.

Morning routine:
12 tasks have to be performed for 14 residents resulting in 168 tasks altogether. The average time per task is 03 : 12 min. The manual documentation time has been estimated as 07 : 30 min per resident, 52 : 30 min per nurse, and 00 : 38 min per task.

Evening routine:
Though the nurse is responsible for more residents the tasks are less intense and frequent. The shift handover takes about 30 minutes. On average, 370 tasks are performed by one nurse per night, taking 420 minutes of the shift. 210 minutes are left for documentation, resulting in an average documentation time of approx. 40 seconds per tasks. The experts were positive, that except for the health status check, all tasks contained in the process model in Fig. 7 can be documented automatically. Again, tests revealed a time of 10 seconds per task for automatic documentation under pessimistic assumptions. The documentation time per nurse will be reduced from 210 minutes to 90:50 minutes.

This means a reduction of 74.34% of time per documentation task, 68% per resident and 64.87% per nurse on average for both shifts. It should also be noted, that in this approach, the identity of the nurse fulfilling a task gets drawn out of the shift schedule. An adaption could be NFC tags placed on the clothes of a nurse as identifier.

6.2 Comprehensive documentation

We tested our implementation and generated forms, following the guidelines of an Austrian nursing home, see Fig. 8. From the point of view of the nursing home there is no drawback or noticed difference regarding the operation without automatic documentation. One perceived advantage by the experts was, that when additional (available but not used) information needed to be included into the documentation, the documentation could be simply regenerated.

In order to evaluate if comprehensive documentation can be achieved, we compared an actual documents covering the morning routine of residents.[10]

According to the involved care takers the created documents would be sufficient. As the care takers themselves consult the documentation of fellow

[10] No personal data that allows to infer on residents is included in the data excerpt presented below

Table 10: Possible improvements through automatic documentation

Task	Morning		Evening		
Residents	14		70		
Tasks per resident	12		3-6 (4.5 avg.)		
Tasks total	168		370		
Worktime (nurses)	540 min.		420 min.		
Worktime per task	03:12 min.		01:06 min.		
Nurses	2		1		
Documentation	Manual	Automatic	Manual	Automatic	Improv.
per resident	07:30 min.	02:00 min.	03:00 min.	01:10 min.	68.00%
per nurse	52:30 min.	14:00 min.	210:00 min.	90:50 min.	64.87%
average per task	00:38 min.	00:10 min.	00:40 min.	00:10 min.	74.34%

care takers, in order to learn details of the residents, they anticipate automatically generated documents to be easier to read, as they all strictly follow the same structure and granularity.

In Fig. 8, a typical paper-based documentation can be seen, while Fig. 9 shows the equivalent in XES.

In the following we elaborate how the data was processed to generate the paper-based documentation. (1) shows the timestamp of the documentation. In the log, the timestamp exists for each task. For the paper-based documentation just the date, not the time is necessary. (N) shows the name of the nurse. The fact that multiple nurses may share the workload for one resident, is reflected in the paper-based documentation. In the log the responsible actor is again saved with each task. (2) documents the behavior of a resident in the community room. In the log that this is a note attached to a certain task. For our current implementation nurses can take audio notes with their smartphone which are automatically converted to text and saved with the last task that was worked on (i. e. activated through a care utility). (3-8) show care tasks as defined in Fig. 1. The text is generated automatically from (1) the existence of the log entry and (2) notes attached to the log entry, as can be for example seen with (6a) and (6b). Tasks (4), (5), and (7) have been omitted in the log to simplify presentation, but look similar to (3). (3+4) in the paper-based documentation are a special case, as the standardized sentence *"The morning hygiene has been carried out"* depends on the existence of multiple tasks.

The newly gained information about the exact point of time an event occurred due to the reading of the NFC tag, can be used to analyze the care process for each resident or of the nurses even, for example, the intervals between intakes of medication. 7

7 Discussion

This section reflects on different aspects that are crucial for the success of automatic task completion and documentation as proposed in this work. At first, the applicability of the approach in the care domain is discussed (cf. Sect. 7.1). The transferability of the approach to other domains such as production are discussed in Sect. 7.2.

7.1 Estimation of Cost Categories

The evaluation showed that potentially a good amount of time could be saved during tasks of documentation. If time can be saved, other aspects are affected as well. In (Jansen-Vullers et al. 2008), the four dimensions, time, quality, cost, flexibility are shown to in relation to each other. In the view of performance measurement, the following points can be established.

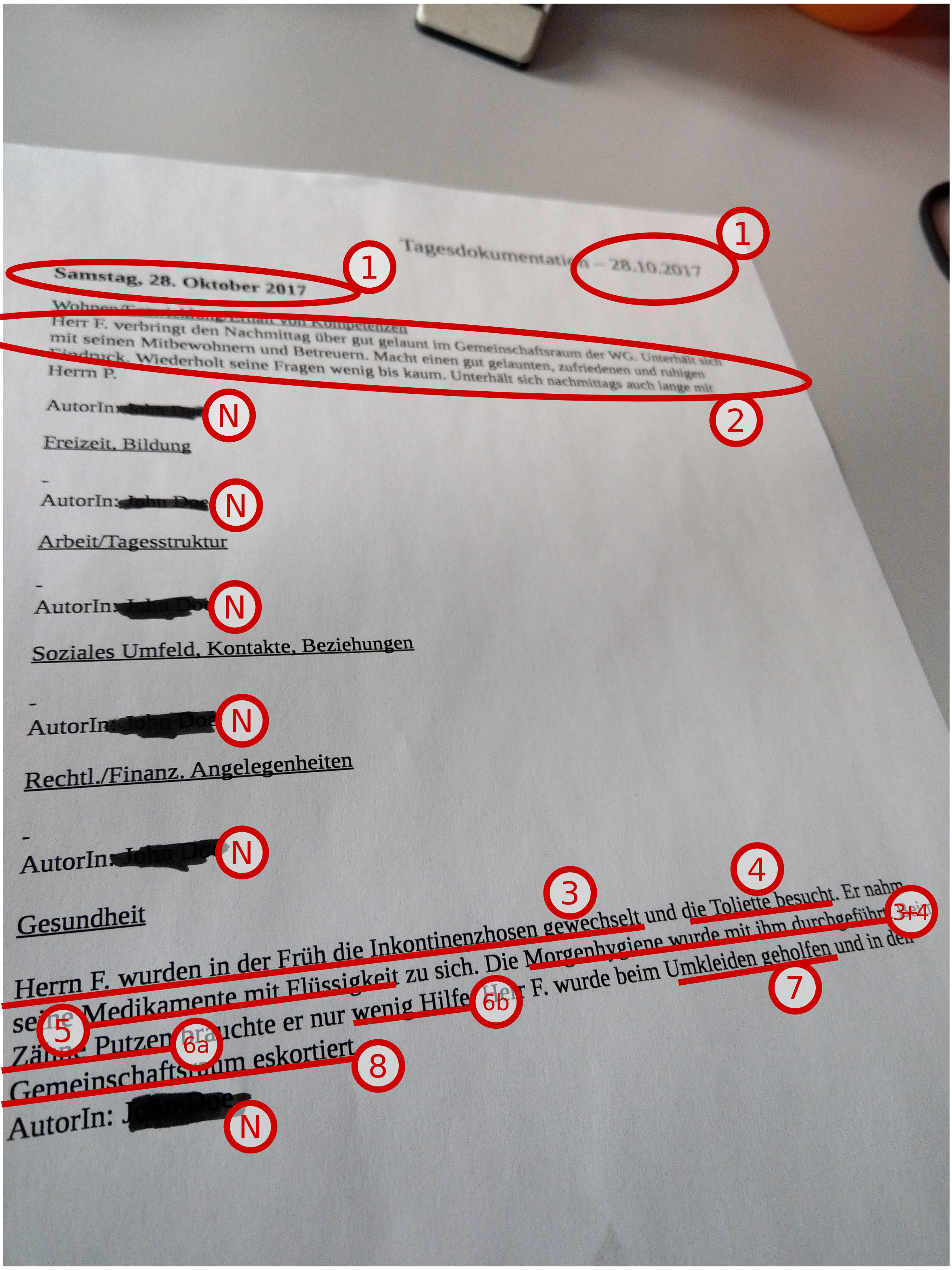


Figure 8: Paper-based documentation

```
<trace>
  <string key="concept:name" value="Resident F."/>
  <event>
    <string key="concept:name" value="Change incontinence Pants"/>
    <string key="org:resource" value="John Doe"/>
    <date key="time:timestamp" value="2017-10-28T06:32:00.000+01:00"/>
  </event>
  ...
  <event>
    <string key="concept:name" value="Brush Teeth"/>
    <string key="org:resource" value="John Doe"/>
    <date key="time:timestamp" value="2017-10-28T06:42:00.000+01:00"/>
    <list key="data_reived">
      <string key="content" value="
        Wenig Hilfe.
      "/>
    </list>
  </event>
  ...
  <event>
    <string key="concept:name" value="Escort to community room"/>
    <string key="org:resource" value="John Doe"/>
    <date key="time:timestamp" value="2017-10-28T06:48:00.000+01:00"/>
    <list key="data_reived">
      <string key="content" value="
        Herr F. verbringt den Nachmittag über gut gelaunt im
        Gemeinschaftsraum der WG. Unterhält sich mit seinen Mitbewohnern und
        Betreuern. Macht einen gut gelaunten, zufriedenen und ruhigen
        Eindruck. Wiederholt seine Fragen wenig bis kaum. Unterhält sich
        nachmittags auch lange mit Herrn P.
      "/>
    </list>
  </event>
</trace>
```

Figure 9: XES log (log-based documentation)

Time Dimension In the time dimension, we take a look at the lead time. The lead time is defined as the time it takes to finish a whole case. A case in our scenario would be the complete morning shift. With the reduction of time spent on documenting tasks, the lead time can be reduced.

Quality Dimension We focus on the internal quality in the quality dimension. The NFC service can provide immediate feedback to the nurses and the documentation is done in an automatic way.

Cost Dimension The cost dimension is directly connected to the time and quality dimensions. With a decrease in the lead time, costs can be reduced. Moreover, a documentation with a poor quality can increase costs, if steps have to be redone or unsatisfied residents file in complaints.

We chose to omit the flexibility dimension in this discussion, since this dimension is untouched from this approach.

While the chosen example on a nursing home, contains only a small number of residents, this solution can easily scale to bigger environments like a hospital. In a hospital the number of persons needing treatment would increase greatly, but also the nursing staff and the amount of hardware. The price of this solution should increase linearly, because we established a one to one relation of NFC reading devices to the number of beds. The number of care utilities used, increases as well linearly, since the same care utilities are used for each person.

7.2 Transferability to other domains

The evaluation indicates the potential for integrating automatic NFC-based task completion into process-aware care solutions. In the following, we discuss which other domains might basically benefit from automatic NFC-based task completion as well.

At first, domains can benefit that possess similar characteristics as the care domain. In (Kaes and Rinderle-Ma 2017; Kaes et al. 2014), several of these domains are identified such as manufacturing and event management. In all these domains, process-aware solutions are expedient. Process instances are connected to different subject, e. g., the patient, the product, or the customer. Process data as well as environmental data plays an important role as well as different actors working on the tasks. Some of these domains such as manufacturing (but also, for example, logistics) are already familiar with the use of sensors. Documentation plays an important role in these domains – for different reasons – as well. Some also are subject to documentation obligations and for some the monitoring of KPIs is daily business. Finally, in all these domains, physical objects are employed in process tasks such as machines in production and goods in logistics. In summary, the factors for a domain to potentially benefit from automatic NFC-based task completion are:

1. Process-aware solution
2. Need for documentation/KPI monitoring
3. Process subjects and / or objects can be equipped with NFC tags and connected to NFC reading devices. A process subject (Grossmann and Rinderle-Ma 2015) denotes the person or item that denominates the process instance, e. g., the resident or the product. Process objects describe in a broader sense data that is processed during process execution as well as physical objects that are utilized for conducting process tasks such as a vehicle, a comb, or an employee card.

Application areas that fulfill the abovementioned preconditions are, for example, manufacturing and logistics. Both crave for process support (Baumgrass et al. 2015; Schulte et al. 2012) and are prone to documentation for quality assurance and traceability (Grob et al. 2009). Specifically in the logistics domain, sensor-based technology such as RFID is already in use (Chow et al. 2007). Moreover, manufacturing and logistics processes employ process subjects, i. e., products and goods/cargo as well as process objects such as vehicles and machines that can all be equipped with NFC technology.

Manufacturing: The applicability of sensor-based documentation in the manufacturing domain was analyzed in the experimental manufacturing environment LegoFactory,[11] at WST research lab. In this setting, several sensors are integrated and utilized anyway. Here the product is the driving factor for the process execution, i. e., the product is to be equipped with an NFC tag and the different machines with readers in order to document automatically that a product has passed a certain machine.

Logistics: Similar to the manufacturing domain, the goods are the process subjects which drive the process execution. Hence, for logistics as already done in practice, goods can be equipped with NFC tags and the utilities for transportation, e. g., the truck, equipped with the readers. This would not only facilitate documentation, but also foster the traceability of the goods on the transport. An interesting question is whether single goods are equipped with NFC tags each or cargo, i. e., bundles of goods. This becomes particularly important for bundling and unbundling of cargo.

Currently, only a restricted amount of data input can be processed through NFC technology, e. g., dosage. For future applications, extended solutions connecting automatic documentation with data input are conceivable as well.

[11] http://gruppe.wst.univie.ac.at/projects/LegoIndustry/index.php?t=project

7.3 Limitations

- The process-aware care solution has been developed using the information from nurses prototypically implemented in a lab setting, i. e., It has not been tested in a real-world environment yet. A process-aware system environment would be beneficial to implement this system, although a data centric approach can be used as well. The disadvantage of not having a process-aware solution, is that information of the NFC tags can only be documented without the enriched information of the ontology and the information of the whole care process. So instead of a glass of water has been given to achieve the task of hydration, only a glass of water would be documented.
- Technical knowledge is required for writing information on an NFC tag, which imposes a burden. This problem can be mitigated with the help of an easy to use software. However, a new task concerning technical interactions is still added to the daily routine.
- If a tag is faulty or contains wrong information, the information has to be rewritten on the tag, even though the medical container could contain the correct medication.

8 Related work

8.1 Process technology in health care

AdaptFlow (Greiner et al. 2004) enables the dynamic adaptation of medical processes, specifically to deal with exceptional situations. AGENTWORK (Müller et al. 2004) is similar in that it provides adaptive process technology equipped with reactive and predictive strategies for exceptional situations based on planning. OzCare (Lee et al. 1996) also deals with flexible support of treatment processes based on a declarative description of the processes. AdaptFlow, AGENTWORK, and OzCare do not support sensor-based task completion and documentation.

(Poulymenopoulou et al. 2012) also focuses on emergency care, in particular on supporting the interaction between emergency services and hospitals. The standard exchange format used is CDA (Dolin et al. 2001) employing a RESTful service orchestration. The latter is similar to ACAPLAN and ACC and no attention is paid to the automatic task completion and documentation.

The approach presented by Anju et al. (Anju et al. 2013) aims at improving the medical documentation. The main application focus in on intensive care units (ICU) where time management is crucial. Hence, this approach assumes manual data input and provides information management on PCs and tables used in the ICU based on apps. These are two major differences to the work at hand, i. e., automatic versus manual data input and web services versus apps.

(Horsky et al. 2006) deals with computerized assistance for emergency facilities based on recommendations for process models. Specifically, it enables the usage of RFID tags in order to update patient records automatically. The work at hand advocates to use NFC instead of RFID due to reasons such as security and minimal invasiveness furthering the acceptance of end users. Gunter (Gunter et al. 2009) also employs Bluetooth and Wi-Fi as well as RFID for identifying patients and updating patient data, more precisely their electronic health records (EHR). The distinction to the work at hand is that this work does not only enable updates of measures for the patient, but documentation of entire tasks as well as opting for NFC instead of RFID for the above stated reasons.

(Prinz et al. 2012) utilize NFC technology in the healthcare domain for enabling patients to report about their health status themselves. (Fontecha et al. 2011) also employ NFC technology for nurse training. Both approaches state that the usage of NFC technology was perceived well by the users, e. g., as unobtrusive and intuitive. This is a helpful observation for the applicability of the solution presented in this paper, although none of (Fontecha et al. 2011; Prinz et al. 2012) proposed or used a process-aware solution aiming at automatic task completion and documentation.

8.2 IoT in Business Process Management

IoT and BPM have grown more closely lately due to, for example, the intensified implementation of process-aware solutions in manufacturing (Mangler et al. 2019). The survey in (Janisch et al. 2020) sets out 15 research challenges at the interface between IoT and BPM, arranged along the process life cycle and the different levels of a PAIS. The work at hand contributes to the following challenges:

- Smart placement of sensor within the processes (C1) addressed by placing NFC tags on care utilities and NFC readers on patient beds
- Visualization of physical processes (C2) addressed by log and paper-based representation and documentation of process execution data
- Autonomy of IoT things (C9) addressed by enabling physical objects, i. e., care utilities, with independent task completion and documentation
- Improving task monitoring and execution (C16) addressed by increasing documentation quality and nursing KPIs

Overall, the work at hand tackles a set of challenges with focus on the integration and empowerment of physical objects in PAIS.

Most of the existing approaches have tackled the integration of sensors into processes. This integration subsumes the modeling and the execution of sensor tasks. A systematic literature study on how to model IoT devices in BPM found that predominantly BPMN is used as modeling language (Torres et al. 2020). (Mottola et al. 2019), for example, proposes to model sensor tasks in BPMN processes, including an adapted task icon and annotated sensor data streams. Then subsequent challenge is to transform the model into executable code. The latter requires *"in-depth programming expertise or extensive configuration"* as stated by Friedow et al. (2018) where again the sensor tasks can be modeled using BPMN. Similar concepts for sensor-equipped tasks are employed in (Suri et al. 2018), especially for configurable processes resulting in different process variants. The work in (Schönig et al. 2019) extends the integration of sensors in processes to guide users through wearables.

The work at hand can use the proposals on how to model sensor tasks. It provides a solution and prototypical implementation for executable NFC-equipped tasks and their processes. The approach requires and supports the interaction of nurses with the system through tables (or other wearables). In summary the approach provides a concrete and comprehensive solution for specific sensors, i. e., NFC, and their integration in processes.

9 Conclusion and outlook

The sensor-based completion and documentation of care process tasks constitutes a crucial edge for nursing homes by relieving the staff and providing a constant quality of the documentation. The paper has shown the potential of automatic documentation for a large share of routine tasks. In the following, we relate the achieved results to the research questions as stated in the introduction.

1. *RQ1: How to provide automatic completion support at any given care task?* and *RQ2: How to provide automatic documentation support at any given care task?*
   The solution for RQ1 and RQ2 is three-fold: (i) providing care use cases that contain and benefit from automatic task completion and documentation; (ii) providing a process-aware care solution; and (iii) equipping it with NFC technology. (i) is necessary in order to be able to identify care task and the requirements for (ii); (ii) supports the execution of care tasks with automatic task completion and documentation by a system. (iii) has be found as suitable way to integrate sensors into the system due to unobtrusiveness and simplicity, i. e., NFC tags and readers are able to store and transmit the necessary information. The design and implementation of the process-aware care solution have been presented.

Problem	**Research Process**	**Solution**
Lack of process awareness in care homes; lack of automatic task completion and documentation support for nurses; high time effort and quality issues in care task documentation for nurses;	Following Design Science Research: Identification and modeling of nine care-specific use cases (→ requirements); solution design; build and evaluate of solution components (technical and practical evaluation)	Set of design choices for a process-aware care solution that features automatic task completion and documentation; communication between NFC-enhanced care utilities and PAIS; extension of process task completion mechanisms; automatic documentation through logging of process execution; tool chain for automatic creation of paper-based documentation from process logs; prototypical implementation based on an open source process engine; interviews with two nurses;
Input knowledge	**Concepts**	**Output knowledge**
Interviews with nurses; morning and evening care routine; experiences with implementing process-aware solutions; cloud-based process execution engine, including components for interacting with nurses from other projects;	NFC-based communication between care utilities and PAIS; extension of process task completion mechanisms; creation of paper-based documentation from process logs;	Care processes and use cases; automatic task completion and documentation in care processes results in reduction of time for documentation; architecture and components for process-aware care solution; useful paper-based documentation can be created based on process logs;

Figure 10: Design Science Research (DSR) Matrix (Brocke and Maedche 2019) filled in for this work.

2. *RQ3: How to enable the automatic generation of paper-based documentation based on process logs?* Different ways of documentation have been presented contributing towards a comprehensive documentation. Log-based documentation is provided for runtime logging and monitoring. The automatically created paper-based documents fulfill nurses' expectations of what they are used to on a day to day basis.

3. *RQ4: How effective is support of automatic task completion and documentation?* Regarding the reduction of effort and time, the results are promising, i. e., more than 60% of documentation time per task could be saved as indicated by interviews with nurses.

Moreover, the potential of automatic task completion and documentation is interesting for other domains as well. The transferability has been discussed for manufacturing and logistics.

Fig. 10 summarizes the contributions and design knowledge acquired during this work in terms of a so-called Design Science Research (DSR) Matrix as proposed in (Brocke and Maedche 2019). The contributions have been discussed along the research questions above. What we do know what we did not before this work is that particularly process-based documentation can reduce the time spent on documentation. Moreover, different formats for care documentation can be offered. Potential stakeholders of the proposed solution are nurses (reduction of documentation effort), nursing homes (improvement of documentation quality and nursing key performance indicators), and the residents (more time with the nurses, potentially improvement of independence). This work focuses on the reduction of documentation effort and therefore on nurses as stakeholders.

The next step is to apply the suggested solution in a real-world setting, i. e., a nursing home. For this we plan to extend the existing ties to cooperations' partners from nursing homes in order to set up a pilot project. In addition, sensor-based task completion and documentation will be applied to other domains such as the manufacturing test lab setting. Doing so furthers the automatic task completion and documentation and serves as basis for investigating the generalizability of the results presented in this work. Moreover, we will continue working towards the application of the solution in real-world care setting.

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