Activity Recognition of Nursing Tasks in a Hospital: Requirements and Challenges

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Abstract. In nursing, the documentation of the nursing activities carried out plays an important role. However, the shortage of nursing staff and the resulting increasing lack of time means that the documentation is often not filled out completely. Human activity recognition (HAR) could assist with documentation by automatically recognising the services performed and entering them into the documentation system. For this purpose, data from different wearable and stationary sensors have to be processed. This paper will describe the requirements to develop such an activity recognition system. These are both functional and non-functional requirements. These requirements have been developed both from a review of current literature and after discussions with nursing students and representatives of nursing management of local hospitals and nursing science. In addition, activities in nursing that frequently need to be documented are listed. The results should therefore serve as a basis for the implementation of a system for the HAR of nursing activities.

Keywords: Activity Recognition · Requirements · Nursing Documentation · Nurse Care Activity Recognition

1 Introduction

In nursing care, both short- and long-term care, it is essential to have information on the patient's activities and nursing records. Nursing documentation contains information about activities that have been carried out as part of the nursing process. This includes aspects of care education, diagnosis, planning, implementation and duration of care. The increasing demands for quality assurance and transparency lead to additional obligations with regard to the documentation. One study confirms a time expenditure of 13% of working time for care documentation, while employees estimate the effort at 20–30% [1,2].

Studies show that employees in nursing suffer from burnout comparatively often. In 2017, a survey showed that almost 40% of nurses suffer from burnout, compared to only 28% in the rest of the population [3]. Dall'Ora et al. have shown that a high workload in particular can lead to burnout. This is also due to staff

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shortages in nursing. Higher patient-to-nurse ratios as well as high time pressure are associated with emotional exhaustion and dissatisfaction [4]. In addition, dissatisfied patients can also lead to this. In combination with low usability of the electronic health record, this is a source of stress and frustration among nurses [5].

Germany's Federal Ministry of Health is planning the digitalisation of the health care system. Digitally supported care documentation should lead to a reduction in the workload of caregivers. Automatic documentation of vital parameters can take place through networked monitoring systems. In addition, a major goal of the digitisation strategy is to increase the syntactic and semantic interoperability of nursing documentation [6].

An examination of existing digitisation projects has shown that the majority of projects (48.4%) relate to the support of people in need of care. These include projects on coping and dealing with illness- or therapy-related stress, projects on social participation and mobility. Only 14% of the work examined is directed at professional carers, with just under half of the projects focusing on documentation, especially the (further) development of documentation systems and the networking and automation of staff and route planning. It is noticeable that most of the work focuses on the outpatient sector (49%), while only 7% of the work is related to stationary care [7].

2 Related Work

To facilitate nursing documentation, digital products in particular are distributed to make documentation clearer and to enable immediate availability of the patient's record. Based on text entries from the assessment and nursing reports, nursing diagnoses and a nursing care plan are automatically suggested. However, text-based entries are tedious and can be error-prone, and in the case of voice-based entries, incorrect entries can occur due to lack of text comprehension and background noise [8].

An alternative to manual documentation, whether typed or by voice input, is the automatic recognition of the performed activity and the automatic documentation in the system afterwards. Both cameras and wearable sensors are used for Human Activity Recognition (HAR). Mainly activities of daily life, such as walking, climbing stairs, or fall detection are recognised [9].

Initial research work is dealing with the HAR of nursing activities. Kaczmarek et al. use accelerometers on the upper body to record activities such as repositioning, transfer and mobilisation. However, the accuracy of the classification was only about 55%, but could be improved with additional information about the caregiver's location [10]. Konak et al. combine accelerometer and image data to record nursing activities, such as helping with dressing or preparing medication. Video recordings are also used to determine the optimal sensor placement for the accelerometer. It is stated that optimal sensor placements are at the wrists and pelvis. However, results for other body regions are not described. With the multimodal approach, recognition difficulties occur when the camera is obscured [11].

Lago et al. use a motion capture system, but they use body markers tracked by infrared cameras. In addition, the acceleration sensors of a smartphone and sensors for localisation are used. Activities such as measuring vital parameters, oral care or washing were recorded. The result shows that only the use of acceleration data is unsuitable for tracking activities. Instead, the other modalities should be used [12]. However, a motion capture system and the application of body markers are impractical. This is because several cameras are needed and several body markers have to be placed all over the body or upper body. This is not user-friendly for everyday use. Carrying a smartphone during working hours also often does not correspond to reality. The acceleration data is provided as part of the Nurse Care Activity Recognition Challenge [13].

3 Aim and Methods

In order to relieve the nursing staff, nursing activities will therefore be tracked and stored in the documentation software as part of the "Data-driven Health (DEAL)" project. It should not be a tracking of the person being cared for or the patient by checking whether he or she has fallen or how much has been drunk. Instead, the system should recognise the activities of the nurse, e.g. whether medication was given or whether vital signs were checked. This should be done in order to automate the nursing documentation and thus give the nursing staff more time for the care and the patients. In contrast to the related work presented, which for the most part have not specified a setting, we want to focus specifically on the clinical setting. The specification is necessary because the scope of the documentation and the activities to be documented depend on it. In addition, the clinical setting is characterised by a more dynamic daily routine than, for example, the outpatient setting [14].

In order to develop a user-oriented technology, nursing professionals are to be involved in the development. By actively involving nursing students in the development process, acceptance problems and barriers to innovation can be reduced [15]. In the context of a World Café with twelve nursing students, initial ideas were developed about which nursing activities need to be documented frequently and which critical aspects need to be taken into account in an automatic activity recognition system. The participants were divided into two groups and discussed the questions for about 30 min each. In addition, representatives of the nursing management and nursing science of regional hospitals were invited as part of a project advisory board. This advisory board will support the realisation of the project and advise on any questions that may arise. In a first meeting, expert feedback was given on which organisational and technical aspects should be considered in the development of a system for activity analysis. The resulting requirements for the system from the World Café and the advisory board will be described in the following.

4 Results

At this point, the requirements for the system should be described first. These are divided into functional (FR) and non-functional requirements (NR). This is followed by a description of possible activities and scenarios that often need to be documented in the clinical setting.

4.1 Functional Requirements

The main task of the system is to recognise activities of a nurse in a clinical setting (FR1). If the system has recognised an activity incorrectly or not at all, it must be possible to correct or supplement the entries (FR2). An activity often consists of several steps. For example, wound care involves removing the dressing, photographing and measuring the wound for documentation, cleaning the wound and applying a new dressing. The system must therefore know the regularly performed activities that are to be recognised, as well as the individual intermediate steps that belong to the activity (FR3). For this, an activity inventory must be defined and relevant data must be collected. The system must make it possible to interrupt an activity and continue it at a later time (FR4). It must also be possible to swap the order of intermediate steps, depending on the nurse's routine. The system should be able to identify the care activity despite the changed sequence (FR5).

The system should also remind the nurse of missing actions (FR6). An example of this would be closing a window on bedridden people when the room cools down. For this, it is important that the system has knowledge of the patient's care plan and diagnoses (FR7). Feedback on the identified activities and ticking off of the care plan must be available (FR8), so that the nurse has an overview of the activities that still need to be carried out.

Often there are several patients in one room in a hospital. The system must therefore be able to distinguish between the individual patients and assign the activities that have been carried out and recognised to the respective patient (FR9).

4.2 Non-functional Requirements

As feedback is important for caregivers, the system must recognise the activities in near real time (NR1). In addition, the recognition rate for identifying the activities must be high (NR2). If the recognition rate is too low, the system will not provide any added value, but will require a lot of time due to the correction of the entries. Therefore, the recognition accuracy should be above 80%. This accuracy was achieved on average in related work [10–12,16]. Good recognition must also be available under changing influences, such as changing light conditions, and it must be independent of gender, body shape and ethnicity (NR3). It is important in detection that no fraudulent activities are recorded. By this is meant that no simulated activities should be detected.

In order for the system to support the nurse in her daily work, the system must be easy to use. Nursing professionals are usually not familiar with IT. The use of this system should not be more complicated than the method used so far (NR4). Sensors used to detect the activities must be easy to attach and not hinder the caregiver in their exercise (NR5). For example, sensors on wrists should be avoided for reasons of hygiene and possible risk of injury. An important aspect of the implementation of such a system is the consideration of ethical, legal and social implications, such as data protection, as patient data is collected. Therefore, the system should be GDPR compliant (NR6). When using cameras for activity analysis, no image data should be stored or processed. The nursing staff should not get the impression of surveillance. Instead, only features read from the data should be used, ideally standardised to prevent later misuse (NR7). Particular attention must be paid to sensitive areas, e.g. in the bathroom, when using video recordings.

There is no uniform standard for nursing documentation, i.e. each facility records it in a different format. Therefore, the data must be standardised or the data model must be flexible and transferable to different application programmes (NR8). In the event of a transfer to another hospital, the care measures carried out must be fully accessible to the new facility. This is possible through the use of two of the most important international standards for the semantic interoperability of clinical information. One is the HL7 Clinical Document Architecture (CDA), which is a widely used standard for representing clinical information in the form of XML documents. The other is the combination of CEN/ISO 13606 and openEHR, which is based on the use of a reference model to represent data instances and an archetype model to represent clinical concepts [17].

It may be possible that the internet is not fully covered in the hospital. This means that captured data cannot be uploaded immediately. Therefore, the system must also be usable offline (NR9). The collected information from the sensors must therefore be temporarily stored so that it can be sent to the database as soon as the system is online again. Since a nurse often works an 8- or even 12-hour shift, it is important that the battery of the hardware used lasts at least one shift without needing to be charged in the meantime (NR10).

4.3 Possible Activities and Scenarios

In collaboration with the nursing students, the activities that often need to be documented in a clinical setting were identified. These are activities that take place within the scope of a given care plan. These include checking vital signs and measuring blood sugar and body weight. But also the mobilisation of the patient and personal hygiene are frequent activities. Other medical interventions include wound care and changing wound bandages, medication management, which also includes intravenous infusions and subcutaneous injections, and nutritional monitoring. Other relevant activities are the preparation of a care plan, patient observation and documentation of the patient's condition and the taking of a social history.

Derived from the requirements and the possible activities, one imaginable scenario is the recognition of nursing activities during the morning routine. This reflects a large part of the activities mentioned (measuring vital parameters, administering medication, personal hygiene, etc.). Inertial measurement units (IMU), such as the xSens DOT, could be used to collect movement data. These consist of acceleration sensors and gyroscopic sensors. It must be investigated at which positions the IMUs must be placed in order for them to provide meaningful data and be suitable for activity detection. In doing so, the NR5 requirement must not be disregarded. The Microsoft Azure Kinect is also conceivable for the recognition of nursing activities. At this point, however, the requirements NR6 and NR7 must be observed so that both the caregiver and the patient are protected. In combination with information about the location, i.e. in which patient room the nurse is and at which patient bed, and further information about the care plan (FR7) and the activities (FR3), the activities can be recognised. This is reflected in Fig. 1, which shows the general architecture. The requirements indicate that, in addition to sensors and location information, background information is also necessary for recognizing and classifying nursing activities. This background information includes the activity inventory with the intermediate steps (FR3) as well as information about the nursing plan or the patient (FR7) and knowledge about the nurse. The recognized informations must then be presented (FR2) so that the nurse can correct them, if necessary.

5 Discussion

The listed requirements show that the detection of nursing activities is a challenging task. The requirement that the activities can be interrupted or that the sequence of the individual intermediate steps of an activity can be changed leads to a high degree of complexity in the detection of nursing activities. The requirement that the sensors must not disturb the caregiver (NR5) is also relevant in consideration of related work. Konak et al. have indicated the wrists as the optimal sensor placement [11], and yet these are not suitable for sensor attachment for injury and hygiene reasons. A critical approach to public datasets and related work considering sensor locations is therefore necessary. Data protection is also an important aspect that must not be neglected in the development of the system. Aspects such as privacy and security must be taken into account here, both in relation to the caregiver and in relation to the person being cared for. Especially when using video or image data, these must be processed to the extent that a human observer cannot draw any conclusions. However, this also increases the complexity of activity recognition, since not all features can be used. Questions about how to both identify and distinguish the caregiver from the patient in a camera-based evaluation need to be answered.

When working with the nursing students, often documented activities were elaborated. These refer to the clinical setting. However, during the inventory, no distinction was made between different departments in a hospital. A possible distinction would be between surgical and non-surgical wards.

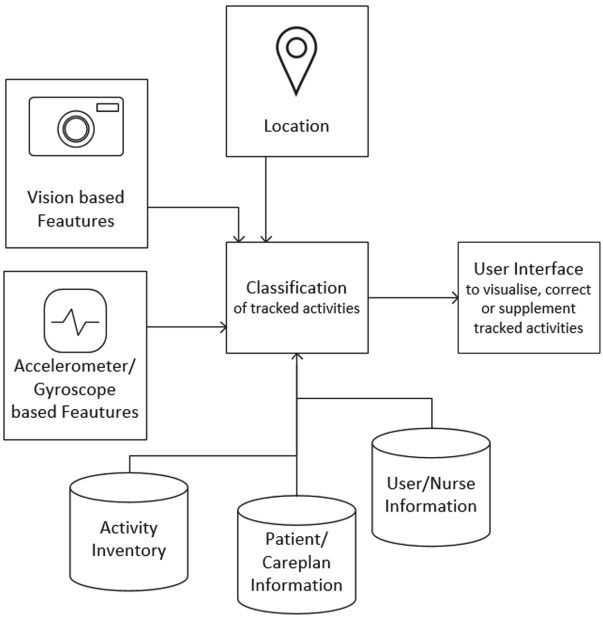

Fig. 1. The general architecture for the recognition of nursing activities. Sensors, location, and background information on activities, patients, and caregivers are used to classify activities. The detected activities are then visualized.

6 Conclusion and Future Work

Nursing documentation is a quality indicator as well as important for achieving good patient care and safety. In this paper we have introduced and collected the requirements necessary for the recognition of nursing activities in the clinical setting. For this purpose, we looked at the current literature, as well as conducted a World Café with students of nursing science and invited representatives of the nursing management and nursing science of regional hospitals as part of a project advisory board. The sensors needed for recognition could be IMUs worn on the body as well as camera-based hardware. However, safety must always be a focus when using them, both physically and in terms of the privacy of the nurse and the patient.

In the next phases of the project, the activities to be recognised are to be narrowed down further and recorded with the help of sensors in a skills lab. For this purpose, it is important to find out which individual steps these activities consist of. In addition, domain-dependent background knowledge must be collected for the recognition. Online surveys and expert interviews will be conducted for these purposes. A more detailed survey could provide results on whether there are ward-dependent differences between the activities that are frequently documented and whether there are activities on which the application should focus.

It can also be investigated whether and how new evidence-based knowledge, appropriate to the recognised activity, can be imparted to the caregivers.

Additionally, in the next phase, the software architecture needs to be determined more precisely. This architecture needs to consider data management and how to ensure that data can be transferred even when there is no connection. The discussion also shows that important questions regarding the identification of caregivers and patients still need to be answered. In cooperation with the project advisory board, the architecture will be validated to ensure that the system is well received.

As soon as a first prototype for activity recognition of nursing activities is available, trained nurses are to be involved in usability tests and further evaluations. This serves to ensure that the system is well accepted.

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