



## Research Article

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# Robot use cases for real needs: A large-scale ethnographic case study

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**Abstract:** This article discusses the process of developing robot use cases using large-scale ethnographic observation as a starting point. In particular, during 296 hours of ethnographic observation of the workflows at seventeen departments at Odense University Hospital, 607 processes were described and subsequently annotated. The ethnographic method provided rich, contextually situated data that can be searched and categorized for use case development, which is illustrated on an example use case, describing the process and illustrating the type of data elicited, discussing the problems encountered and providing downloadable tools for other researchers interested in similar approaches to use case development.

**Keywords:** use case development, ethnography, health care, innovation, welfare robots

## 1 Introduction

Current demographic change means that the ratio between citizens above 65 years of age and those who are between 18 and 64 years old is predicted to increase from 23.6% in 2010 to 42.8% in 2040 on average across Europe [1]. In this period, the proportion of citizens aged 80+ years is ex-

pected to increase from 4.1% to 8.4%. Hence, not only will the share of elderly people increase, the share of citizens aged 80+, who have a substantially higher prevalence for multimorbidity [2], is expected to more than double. This implies that the overall demand for health-care services is likely to grow. At the same time, the health-care sector is under pressure already today, both financially in terms of limited funds but also due to a shortage of qualified staff.

Riek [3], for instance, suggests that robot technology can contribute to the mitigation of the challenges imposed by the demographic change and prove beneficial for stakeholders from various areas across the health-care domain. However, although robots are entering our daily lives in various contexts, robots are rarely utilized in the health-care domain, which might be due to the high cost for robots; it is also possible that the solutions may not be tailored sufficiently to the users' real needs [4], which hinders the adoption of robots in the health-care sector.

But how can technologies be developed that truly support caregivers or patients and help mitigate consequences of demographic change? How can this be done in socially acceptable ways that are in accordance with our social, societal, ethical and environmental values? Often, technological development is driven by what is technically possible, and ethicists and human interaction experts are only brought in to advise the process [5]. Ethnography with its holistic, socially situated approach and its focus on both emic and ethic perspectives (e.g. [6]) can contribute to the development of technologies in a value-driven manner, i.e., governed by axiological analysis and evaluation [7], by providing detailed descriptions of current workflows and of those practices by means of which people address real tasks in real-life contexts themselves. These descriptions allow us to identify repetitive and possibly strenuous tasks that can be automated and which thus might provide help where it is really needed.

In this article, we therefore argue that an ethnographic analysis is a useful perspective on use case development, i.e. a methodological approach to identifying for what purposes technologies are to be developed and how these purposes fit into general contexts of human work practices. To

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understand how robots could be utilized in the health-care domain and how technologies interact with patient care, in particular in hospitals, a large-scale ethnographic case study was conducted, which includes observation and interviews of hospital staff across departments. The observations also cover, though indirectly, interactions with patients. Based on the generated knowledge on the work flows at the hospital, an example use case for a robotic solution is synthesized. The article describes the process and illustrates the data elicited, discusses the problems encountered and provides downloadable tools developed in the project as a resource for other researchers interested in similar approaches to use case development.

## 2 Related work

Ethnography is a well-established method for the description of human practices [8]. The method was first applied to the analysis of human-technology interactions by Suchman [9], who analyzed interactions between two users and a photocopying machine in order to illustrate the contingent moment-by-moment situated action by humans in contrast to the fixed plans implemented into the machine. The method is now also relatively common in human-robot interaction research and robot development, for instance, to understand how robots fit into, and possibly influence, the workflow [10]. For example, Mutlu and Forlizzi [11] show that the same robot may be perceived very differently depending on contextual factors, which determine how the robot is integrated into the current workflow.

Other uses of ethnographic analysis in human robot interaction concern unconstrained interactions of robots 'in the wild'; for instance, Chang et al. [12] find that when robots are moved out of lab settings and are left for intended users to interact with in the ways they choose themselves, the results are very different from results obtained in lab studies, and robots may not elicit the same kinds of anthropomorphic, friendly behaviors. Similarly, Forlizzi [13] and Sung et al. [14] investigate how cleaning robots are used in peoples' homes, and Sabelli et al. [15] present an ethnographic study on a conversational robot in an elderly care center.

Also in use case development, ethnographic observation may be employed [10, 16], but if so, it is usually carried out on a much smaller scale; in our own use case development in the SMOOTH project<sup>1</sup>, for instance, we car-

ried out a 24-hour ethnographic observation, supported by focus group and prototyping techniques [17]. For comparison, other studies using an ethnographic approach in hospital settings collected, for instance, 120 hours [18] or 148 hours [19] of observation, or they followed doctors for 32 shifts [20] and with a specific, predefined topic of interest. In contrast, in the current study, we carried out a thematically relatively open, large-scale observation comprising almost 300 hours in a large, complex and heterogeneous institution, namely the Odense University Hospital (OUH). What makes ethnography particularly suited to approach the current task is its "strong emphasis on exploring the nature of a particular social phenomenon, rather than setting out to test hypotheses about it" [21], its holistic, socio-culturally situated approach (e.g. [6]), and its focus on members' own perspectives (e.g. [22]).

## 3 Case study

The study presented here aims to identify stakeholders' real needs in their current work practices at a hospital. In particular, the project's aim, to identify those tasks that could be taken over or supported by technology, freeing the personnel for those tasks that involve social interaction, was developed in cooperation with Odense University Hospital, which also sees a need to accommodate to demographic change in the near future, but which also generally seeks to optimize care and treatment processes and to involve patients wherever possible.

In order to carry out a large-scale ethnographic observation study, many observers are needed. Therefore, the first challenge was to train a fleet of students to carry out the observations. Furthermore, we needed to provide our observers with observation and reporting guides; our first steps taken were thus communication design tasks, which we describe in Sections 3.1.2 to 3.1.3. Other tasks were organizational and communicative in nature; for instance, the hospital departments had to be identified and contacted, the student observers' schedules had to be managed, and questions had to be answered (see Section 3.1.4). Finally, once the data had been elicited, a coding scheme had to be developed to distill the use cases out of the many observations made. This process is described in Section 3.3. The envisioned use case development process is illustrated on an example use case, which is presented in Section 4. In the discussion, we address especially issues of the post-processing of the observations made and discuss possible alternatives to the procedure taken, as well as the next steps.

<sup>1</sup> smooth-robot.dk

### 3.1 Preparing the ethnographic observation

In order to prepare the ethnographic observation, we first recruited students from various relevant disciplines, but it turned out that only students from welfare technology study programs at the University of Southern Denmark applied. We therefore developed a training session for the first six students, which we videotaped and iteratively revised during each additional training session. In total, 6 + 4 + 2 students were trained, of whom eight regularly participated in the observations. Furthermore, in order to provide students with some guidelines what to observe, we developed a booklet that they could take with them to the hospital to note down their observations. Here we adapted observation guides from previous ethnographic work (in particular, [23]) with special focus on those dimensions that are particularly relevant for the purpose of identifying repetitive and stressful activities. Moreover, we developed a reporting form for each of the processes the students encountered over the course of an observation, as well as a page to provide an overview of what was observed, who was accompanied and where the observation took place. These resources, which are described in more detail in the following subsections, can be downloaded from our website <sup>2</sup>.

#### 3.1.1 Designing the training

The training was designed to be doable in about a day, including four exercises in which students could practice ethnographic observation. The introduction covers methods for collecting and sharing observations, as well as what to focus on during observation, the level of detail required, the neutral, descriptive stance of the ethnographic observer and that nothing is taken to be self-explanatory or obvious. After each exercise, thoughts and problems arising were jointly discussed.

In the first exercise, students had to describe what they see, first without a focus, then with a given focus, in order for them to become aware of the role of one's own preconceptions, but also to realize that one cannot observe everything and that a particular perspective is necessary.

In a second exercise, students practiced interviewing by asking each other about their backgrounds, hobbies and favourite activities. In the discussion, we also covered how to ask politely but efficiently and how not to inter-

rupt or disturb the professionals during their activities. Therefore, we advised the students to navigate between observer-participant and participant-observer roles, depending on the affordances of the current situation [22], aiming for a maximal understanding of what was going on while not being in the way when the situation was critical.

A third exercise addressed how clear the notes have to be in order to be understandable for others who were not present. For that purpose, two volunteers were recruited; one was blindfolded while the other had to wait outside. The blindfolded person then had to make tea using a special, non-obvious tea maker, while the others had to observe and take notes and finally use their notes to explain to the person who had waited outside what exactly had happened.

Finally, the training concluded with a video description task, for which students got detailed, individual feedback from one of the project PIs. This step served not only to provide students with helpful feedback and to ensure high quality observation, but also to make sure that we only send qualified students to the health-care institution.

The training was evaluated by gathering feedback from the students using a questionnaire, in which we asked how prepared they felt and what questions were still open. Students general felt well prepared, and most of the open issues concerned issues we could not answer ourselves at the time, such as how students would get access to the building and what they would need to wear. The training was slightly revised after analyzing the first set of observation reports; in particular, we chose videos for the exercises that were more relevant for the actual observation task, and the booklet was introduced earlier during the training and used for some of the exercises already.

Students were not informed about the main aims of the project in order not to restrict or bias what kinds of processes they would describe and report on. Furthermore, even if they had known the focus of the project, they did not bring in a solid background in robotics that would have allowed them to assess the feasibility of a potential robotic solution. We provided them with a very generic flyer, which stated as the general goal of the project to understand workflows at the hospital for identifying where help would be beneficial (to mitigate demographic change). The flyer (also downloadable from our website) was used whenever staff members or patients at the hospital asked about the purpose of the observations.

<sup>2</sup> [https://www.sdu.dk/en/om\\_sdu/institutter\\_centre/idk/projekter/human-robot+interaction/downloads/welfare](https://www.sdu.dk/en/om_sdu/institutter_centre/idk/projekter/human-robot+interaction/downloads/welfare)

### 3.1.2 Designing the booklet

The aim with designing the booklet was to help observers during their observations in terms of what needs to be reported. Since the students were not completely informed about the aims of the observations, we had to guide them into reporting the right level of detail without them knowing what was going to happen with their observations afterwards.

Furthermore, the booklet needed to be practical. We thus designed a small booklet in B5-format, ideal for being carried around. Each left side of the booklet presented a schema with 14 questions to be filled out for each process observed, in particular:

- where does the observation take place?
- who is observed?
- are additional people involved, and if so, who are they?
- what kind of activity is observed?
- what is its duration?
- what are the subtasks?
- what is the context like?
- how often does this activity occur?
- how stressed (on a scale from 1-5) are the participants?
- how crowded is the space (on a scale from 1-5)?
- is it important that the task is done right now and if so, why?
- are special competences required?

On the right hand side of each double page, enough empty space for the observations was provided.

After the first observations, it became clear that we had to specify some of the questions further. Thus, we included a redesign iteration, in which we specified what we meant by the frequency question; now we ask how frequent each process is carried out by the individual observed (per shift) and how frequent the task is carried out by the department (estimation by the personnel). Furthermore, for data protection reasons, we made it explicit that students should report only the role or title of the person observed, not their name. We furthermore added explanations to the questions about stress levels and crowdedness. These additional explanations were added to the reporting template (see Section 3.1.3 below) and communicated by e-mail to the observers.

25 copies of the booklet were printed and handed to the students for their observations. The students reported the booklet to be a very helpful tool throughout their observations.

### 3.1.3 Designing the reporting template

The aim of the design of the reporting template was to facilitate the comparison of all the collected data and to categorize them afterwards. Furthermore, it was meant for us to be able to understand in detail what happened during the processes observed and what the circumstances were under which they were carried out. At the same time, it was meant to serve as a guideline for the students how to observe and report on the observations as clearly and as non-judgmentally as possible. After the first reports, we made a few adjustments to the reporting template: First, the template was updated to accommodate the updates in the reporting schema in the booklet. Second, we asked the students to provide one overview page in which they present the described activities and who they observed (sometimes students followed several different staff members) in temporal order. In the final version of the reporting template, the following five tasks were specified:

1. Provide an overview: name of observer, date, department and people you observed.
2. Provide a brief glossary of special terms used in the department which need clarification for laypeople.
3. Describe the observation day. In this section, describe all of the observed activities, using the questions from the booklet and making use of all of your notes; use a new schema from the booklet for each new activity. Add photographs or other materials.
4. Report on all other observations that you found relevant, yet that do not fit into the schema.
5. Optional: Describe your impression of your day, thoughts and comments.

We furthermore read through all reports closely and provided students with feedback on their reports from the perspective that we had to be able to have a detailed mental image of the process observed after reading their reports. This feedback turned out very helpful to the students and increased the quality of the reports.

The reports were anonymized by replacing staff or patient names mentioned. Furthermore, the observers' IDs were removed. Finally, the reports were labeled with a numerical ID as well as with the name of the observed department and the date of observation and saved on a certified, locally hosted server with restricted access.

### 3.1.4 Managing the observations

Departments at the hospital were selected and contacted in collaboration with Centre for Innovative Medical Tech-

nology at Odense University Hospital. Representative types of departments from Odense University Hospital in Odense and in Svendborg were selected in order to achieve an even distribution between wards for short and long stays, outpatients clinics and service departments, such as the pharmacy (see Table 1 for an overview on all departments involved). The heads of twenty departments were contacted with a short description of the project aim and design. Three departments were not included in the final project due to late or no response. The departments were in general not informed about the main aims of the project in order not to restrict or bias the observed work task. However, the heads of department were sometimes provided with additional information to generate interest in the project and to establish a contact to the relevant leading staff member. Occasionally, this information was passed on to the staff such that suggestions were made concerning what areas could be particularly suitable for observation.

The duration of the observations and which shifts were covered was planned with each department individually via e-mail. Since the departments found night shifts too sensitive or intense, night shifts were dropped from the investigation. The clinics operate only during the day anyway.

The observation times and dates were planned according to the wishes and requirements of the departments and the students' schedules. The students participated in the departments' work flow from the beginning of the shift to the end or when the staff assessed that observation was sufficient (and additional observation would not yield additional data except repetition).

Prior to the observations, each student signed a non-disclosure agreement and delivered it to the department.

### 3.2 The ethnographic observations

The students, who had been trained by means of the procedure described above, spent typically 6-8 hours per shift per department.

Prior to the observation, the students received staff clothes, name tags and an introduction to the department including instructions concerning special requirements regarding hygiene. The students primarily observed one staff member at a time, but during shift changes, the students were sometimes assigned to a different staff member. During the observations, the students acted mostly as "fly on the wall" and avoided interacting with patients or staff in order not to disturb the workflow. Subsequently, however, students had the possibility to ask the staff questions

**Table 1:** Overview of the departments involved in the study grouped by type. \* indicates departments located in Svendborg, Denmark; the remaining departments are located in Odense, Denmark.

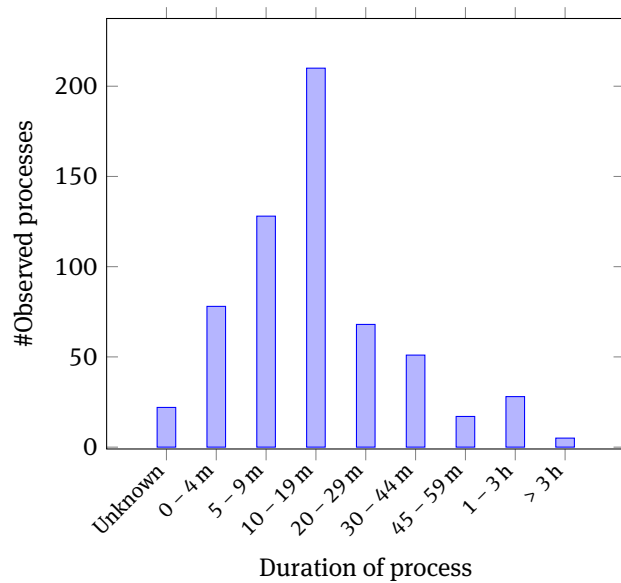
Department	Type	Hours		Processes	
		Early	Late	Early	Late
Emergency (CAP)	Ward	9.0	0.0	15	0
Haematology	Ward	5.0	5.0	11	18
Gynaecology	Ward	25.0	0.0	37	0
Nephrology	Ward	11.0	10.0	35	22
Gastrointestinal*	Ward	14.0	4.5	28	8
Geriatric*	Ward	9.0	8.0	29	17
Otorhinology	Clinic	17.5	0.0	22	0
Radiology	Clinic	12.0	0.0	19	0
Hemodialyse	Clinic	15.5	4.5	24	12
Geriatric*	Clinic	3.0	0.0	9	0
Emergency*	Clinic	7.0	7.0	18	33
Cardiology*	Clinic	12.0	0.0	39	0
Respiratory*	Clinic	6.0	0.0	14	0
Logistic	Service	27.0	0.0	49	0
Cleaning and & Hospital service	Service	21.0	18.5	38	29
Pharmacy	Service	20.0	0.0	45	0
Biochemistry & Pharmacology	Service	13.0	11.5	20	16
Total		227.0	69.0	452	155

about the processes, stress level and so on. Occasionally, they also assisted the staff by finding equipment or with helping with minor care tasks.

Students were equipped with a simple digital camera, and they were encouraged to take images that did not include patients or staff. In case staff or patients were visible in the image, students were equipped with a form for declaration of consent which they then asked the respective person to sign.

Seventeen departments at Odense University Hospital in Odense and in Svendborg allowed our students to observe their daily routines; Table 1 provides an overview of the departments involved in the study, the accumulated number of hours of observation during early and the late shifts, and how many processes were identified in each department. In sum, the observations lasted for 296 hours and yielded 607 described processes.

The students were introduced to the relevant staff by the heads of department, who in a few cases also provided information about the purpose of the observations (see Section 5 for discussion). The processes identified make up approximately 210 hours of the 296 hours of observation reported. Potential explanations of this discrepancy include transition times between processes or short breaks. Furthermore, if several very short processes occurred consecutively, it is possible that students may not have been



**Figure 1:** The distribution of the reported processes with respect to their duration. For 22 processes, the duration was not reported, and five processes had a duration exceeding three hours.

able to cover all processes in the necessary detail and thus left some out.

The distribution of the processes with respect to their duration is illustrated in Figure 1. The majority of the processes reported was found to have a duration of 10-19 minutes. However, 28% of the processes have a duration of 20 minutes or more, suggesting that some of the processes may be rather complex.

Three example of process descriptions can be found in Appendix A; they illustrate the categories we had provided the observers with and how the observers have addressed them, how the observers chose themselves to define the processes, and that some processes may consist of several subprocesses or involve different activities.

### 3.3 Data analysis

The purpose of this study was to identify similar or repetitive processes in a complex working environment; thus, the aim of the data analysis is not to arrive at a synthesis or to condensate the multitude of complex processes observed at Odense University Hospital, but rather to be able to retrieve and organize processes with shared features. Consequently, we decided against a data driven, bottom-up categorization process (e.g. grounded theory or affinity diagrams [24, 25]) and went for data annotation instead so that it will be possible to retrieve the complete, contextu-

alized process descriptions by searching for particular features.

The coding scheme was iteratively developed after the first observations had come in. We annotated for recurrent patterns that have some significance for the development of use cases (see also [10]); here, our background knowledge about important distinctions in robotics (for instance, manipulation requires very different robot hardware and scene understanding than transport) informed the category development. The data analysis consequently consists of the development of a mark-up to retrieve repetitive processes with similar requirements for potential automation.

We therefore pre-sorted the processes observed according to the kinds of tasks they involve, in particular, whether they are logistic, administrative or communicational in nature or involve manipulation of any kind. These were then subdivided further; for instance, logistic processes were subdivided concerning what was moved, for example, food and beverages, critical items, like blood or medicine that require special handling and have to be moved under special constraints, clean goods versus goods that may invoke special hygienic considerations, and those that involve patients themselves. Furthermore, for each process, we thought it useful to know the temporal and spatial constraints under which they take place (stress level and crowdedness of the environment, see [11]). Furthermore, we coded how many people were involved in the process (primary and secondary) and what level of expertise these brought in.

We also coded how often each process was observed and how long it lasted. In general, the index was heavily based on the questions addressed in the booklet and the reports; some categories were added, for instance, information on privacy and data handling requirements (sensitive data, non-sensitive data, no need of information), and current challenges, such as whether the current way in which the processes are carried out causes physical/ergonomic, psychological, organizational, documentational or other challenges for the personnel. The full coding scheme applied is provided in Figure 2.

After a first round of encoding during which multiple project members encoded the same reports, we compared our results, discussed whether everyone understood the categories in the same way and identified ambiguous categories. This led to changes in the categorization of the handling of equipment; here we distinguish now between large equipment (on wheels) and small equipment (handheld). Moreover, the category *influence on patient* was added, to indicate whether a manipulation task influ-

		Stress [1-5]		3	2				
		Crowdedness [1-5]		3	3				
Current challenges	(enter 1 if applicable)	Other challenges							
		Documentational			1				
		Organizational							
		Psychologically							
		Ergonomically/physically		1					
Privacy	(select one)	No need of information							
		Needs non-sensitive data							
		Sensitive data (e.g. CPR)							
Specify the expertise		Collaborating person(s) (enter number of persons if > 0)		1	1				
		Patient or relatives		1	1				
		No Education							
		Short Education							
		Medium Education							
Observed staff (enter 1 if applicable)		Long education							
		No Education							
		Short Education			1				
		Medium Education							
Observed staff (enter 1 if applicable)		Long education			1				
		No Education		1					
		Short Education							
		Medium Education							
Nature of task (enter 1 if it applies, multiple selections are possible)		Number of different subtasks		7	1				
		Admin		Documentation (paperwork)					
				GUI for handling patient data					
				App. (for requesting a service)			1		
		Communication		Remote (phone call)					
				Face2face		Internal communication			1
						Patient		1	1
		Manipulation		Equipment		Small (Handheld)		1	
						Large (on wheels)			1
				Non patient-related		Other			
						Manipulation (dosage medicin)			
		Patient-related		Cleaning					
				Other					
				Handling patients		1	1		
				Medical treatment or examination					
Logistics		Equipment		Small (Handheld)		1			
				Large (on wheels)			1		
		Food or beverages							
		Critical items							
		Clean stuff		1	1				
		Waste & Laundry							
		With patients							
Time		Frequency of observed staff		3					
		Frequency at department		10	99				
		Duration [min]		10	5				
ID Label		Name of activity		14	1				
		Report		6	1				
		Process		12	4				

Figure 2: Semantically grouped categories used to label the processes based on information in the reports. The description corresponding to the examples are provided in Appendix A.

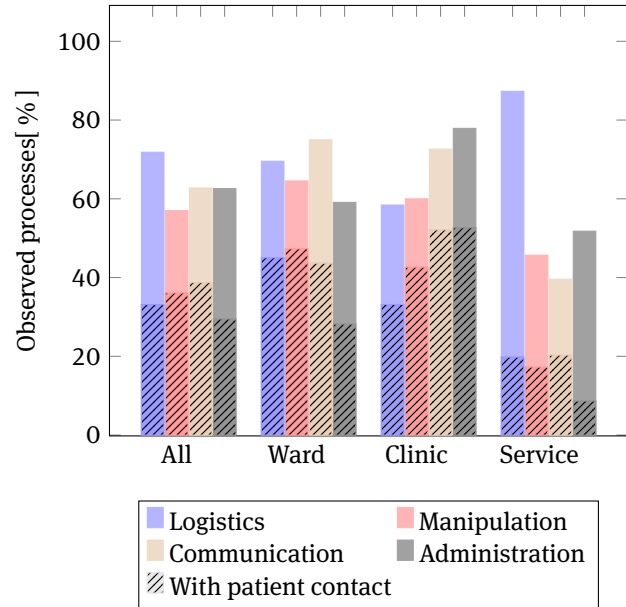


Figure 3: The distribution of the processes wrt. to type of the actions involved (indicated by the color) and whether a patient is involved or not. Since a process might be composed of multiple actions of different type, the different types sum up to >100%.

enced patients directly or not. This category is used for manipulation and logistics tasks.

However, during data analysis, it turned out that the coding is still too coarse grained to allow for the automatic extraction and grouping of all relevant processes; the different steps taken are illustrated in the example use case development in Section 4 below.

The distribution of the processes (see Figure 3) differs with respect to the type of department: For instance, unsurprisingly, in service departments, logistics tasks dominate, whereas in clinics and wards a higher share of communication tasks was observed. Furthermore, processes at the service departments involved substantially less patient contact than at the wards and clinics. Since processes may comprise multiple subtasks, such that a process involves, for instance, both logistics and manipulation, the sum of shares of all types of processes exceeds 100%. About 80% of all processes have been found to comprise multiple subtasks, indicating that additional post-processing to break down processes will be useful.

## 4 Example use case synthesis

In the following, a selection of the observed processes, picked based on the categorization, will be presented, briefly characterized and then used to synthesize one ex-

ample use case. In particular, the procedure for us researchers was to go through all observation reports and to code each process according to the developed schema (see Figure 2). We then grouped the processes coded according to various parameters. In this way, several use cases have already been determined, an example of which is presented below in Section 4.1, but we assume that a plethora of different use cases, for robotic applications as much as for other technology development, will emerge over time.

#### 4.1 Analysis of processes

Based on the categorized processes, a small batch of processes with similar properties was selected, analyzed and used to derive a first use case, i.e. to identify a situation in which a robot may successfully support the current work.

One task emerged to be relevant in various departments, namely the transportation of patients, of which  $N=69$  logistic processes involving patients were identified. We furthermore distinguished those logistics tasks in which patients were the object of transportation ( $N=38$ ) from those in which patients were involved in other roles.

The majority ( $N=16$ ) of the remaining processes involved the transportation of patients lying in beds, but also the transportation of beds without patients. Since the beds are heavy and can be difficult to maneuver, a motorized device can be used for support (see Figure 4). However, the usage of this device is restricted to the basement since this area is inaccessible to the public, and thus potentially dangerous contacts with patients or relatives are minimized. Common to most of these processes is that also communication plays a role, in particular between the service assistant who transports the bed and the patient, for instance, by greeting and informing about the planned journey. Furthermore, communication with staff at the pick-up or target location was observed, mostly for organizational purposes, yet sometimes also waiting times occur if the patient is not ready yet or is expected to be transported back soon.

Guidance of walking patients, for instance, when they are being discharged, was observed in  $N=7$  processes. In addition to guiding the patients to the right location, the observed personnel were typically required to find and identify the patient and to support him or her both physically while walking as well as on organizational matters. Helping the patient into a vehicle, for instance, was typically not part of the guiding but within the responsibility of another staff member such as the paramedic on an ambulance.



**Figure 4:** *MoovingBeds*, a supporting tool for the transportation of beds at Odense University Hospital.

Furthermore,  $N=3$  processes concern service assistants transporting patients using wheelchairs, for instance to get patients to a medical examination in another department. These logistic processes included communication attempts. In particular, while walking, the assistants were observed trying to talk to the patients; however, because of the wheelchair, communication was not easy as assistant and patient could not see each other.

The remaining processes were of diverse nature, comprising actions like relocating the patient from an examination bed to an ordinary bed, and are thus not addressed further here.

The most common type of task was thus the transportation of patients using a bed, which is typically done by service staff who are called, for instance, by nurses when patients are ready to be transported. A service assistant is then assigned to the task and will pick up the bed and move it either locally at the ward or via elevators and the basement to a different department. In the basement, motorized support devices (see Figure 4) are supposed to be used for ergonomic reasons and to ensure safety since the floor has strong slopes. However, the usage of such a device was sometimes considered inconvenient and hence omitted. Furthermore, some staff members found that the dimension of the combined device and bed makes it even harder to turn. Finally, the device was often not placed where it was needed, or its battery level was too low. Thus, the device was not used as often as intended.



## 4.2 Potential robotic solutions

Different options for supporting the transportation of beds can be considered. A semi-autonomous solution (see [26] for an example), where the bed is motorized but still controlled by a human operator, would relieve the staff from the physically demanding work. Depending on the sensors and the kinematics, such a motorized bed might also assist the operator during complex maneuvering. However, such a solution would not address the organizational problem that assistants often had to wait for the patient to be taken back.

If also organizational aspects in the work flows should be addressed, an autonomous mobile robot for the transportation of beds could be envisioned. Even though autonomous navigation in semi-structured and known indoor environments of this type may scientifically be considered to be a largely solved problem, many capabilities besides navigation may be required in the context of patient transport. The ethnographic observation suggests that such a robot would likely be required to interact with patients, inform both patients and staff about its current mission and potentially also respond to requests from the patient, both during pick-up and delivery. Such capabilities are not trivial to achieve for interactions with healthy people and are particularly difficult for interactions with patients who are challenged by their condition. Furthermore, legal and safety aspects when transporting patients with autonomous devices may be challenging.

## 5 Discussion and next steps

In the following reflections on the methodology outlined above are provided and some future steps as well as potential adjustments are considered. In particular, the qualification and guidance of the observers (Section 5.1, the annotation of the data (Section 5.2) and the development of use cases (Section 5.3) are addressed below.

### 5.1 Reflections on the observations

It seems that the training, booklet and coding schemes served their purpose well to provide observers with enough guidance to provide rich descriptions that allow complete recollections of the observed practices without constraining them too much or biasing the observations with respect to possible preselections concerning what may be judged as potentially suited for automation. In this connection, it is relevant that in spite our efforts to keep

observers and observed relatively uninformed about the exact aims of the project, during the later phases of the observations, the heads of the participating departments themselves spread the information that the aim was automation. Correspondingly, they pointed our observers to particular areas to observe and paired them up with staff involved in processes of which they thought they may be suitable for technical innovation. Some staff members also said jokingly that they were doing all those tasks they considered boring and repetitive and of which they would have liked a robot to carry them out. While this compromises slightly the unbiased observations we had aimed for, it illustrates how positive the attitude by staff and administration towards the project really was. Given the busy schedules of the personnel observed, it is in fact quite unlikely that they were able to change their schedules to accommodate the aims of the project. However, it emphasizes the importance of choosing the information shared with the involved parties carefully in order to ensure not to bias the observations.

### 5.2 Reflections on the data annotation

Regarding the mark-up, it has become clear that further iterations are necessary. One problem concerns the unit 'process', which we basically left our observers to define themselves. Many of the described processes are longer than 20 minutes (see Figure 1) and are thus likely to be composed of smaller subprocesses, which may be suited for automation to different degrees and should be handled separately. For instance, the process of changing a diaper can be broken down into logistics (fetching the clean and removing the used diaper) and manipulation (washing and changing the patient) processes. Our analysis indicates that only 12% of the observed processes consist of a simple task, and the average number of different tasks per observed process is 2.5. This would call for a subdivision of the processes observed that would increase the likelihood of identifying similar processes across departments and hence to develop use cases that generalize. On the other hand, a subdivision would present processes as separate although they actually occur in the context of a larger activity and depend on each other. This information may be lost if processes are decomposed. Moreover, when breaking down the processes into different components, we will lack precise information about the duration of the individual subprocesses.

Furthermore, during the analysis it became clear that many more possibilities for searching the processes would be useful. Thus, we understand the mark-up process as on-

going and will continue expanding the coding of the data, which is in line with other approaches to qualitative research (see, for instance, [24]). As a next step, all processes will be semantically annotated with a set of keywords still to be determined.

When we consider the results of the current procedure in the light of possible alternatives, one may ask, for instance, whether the process for the observers might have been sped up if we had equipped them, for example, with a tablet with pre-specified questions. This would have solved one practical problem we had not anticipated: for reasons of hygiene at the hospital, observers were not allowed to use their own watches, and the frequent use of their smartphones for measuring time was considered inappropriate; thus we only have sparse data on the duration of processes and their parts. A tablet would have facilitated the observations regarding duration, as well as with respect to digitizing the observations made. Drop-down menus, for instance, could have facilitated the reporting and even the encoding, since observers could have ticked off the respective categories already. However, such an approach comes also with several disadvantages: First, while the relevant criteria are available now, they were not in place when the observations started, and as described above, they are still under development. Second, the available options could have biased the observers, subtly guiding them into reporting on only those aspects of the processes that are relevant from the perspective of automation, thus reducing the richness and context-sensitivity of the data. Third, a tablet is hard to handle when observers are walking or standing without support of the tablet. Here, the old-fashioned booklet was much easier to work with. Moreover, a tablet may have intimidated staff or patients. Finally, creating reports that provide complete accounts of each process in a second step also forced our observers to check for completeness and consistency of their reports. Had this step been eliminated based on the fact that a digital version of the observation report was already available, this additional inspection and revision process would have been left out.

The overall process was complex and timeconsuming, but the obtained field observations provide complex insights into the workflow at a large institution and indicates the health-care personnel's needs for support in their real-life tasks. This type of information is typically not available otherwise, such that this study can provide unique insights on where and how staff and patients at hospitals can benefit from robots and other technologies.

### 5.3 Reflections on the use case development

While the ethnographic approach led to the identification of detailed descriptions of contextually situated practices, precautions need to be taken in the steps to come. So far, the post-processing of the data consisted entirely of marking up the data with respect to features that are relevant from an automation perspective; consequently, the richness and context-sensitivity of the data obtained in the ethnographic observation are preserved. Since also the challenges the participants themselves experienced and voiced during the execution of the practices were recorded, we have indicators for potential problems where help is really needed. However, by simply grouping the data to identify potential use cases, these challenges do not necessarily drive the use case development process. Here, participatory user-centered design will have to be used in order to ensure that the technological solutions developed really meet real needs (see [27]). Nevertheless, the ethnographic observation yields detailed information on how the technology has to fit into the workflow in order to be useful (see [11]). The very large number of observations provides a good overview of much of the work carried out at the hospital (even though night shifts, for instance, were not observed), which leads to the identification of potential overlap between processes, and thus of requirements even across departments. For robot use case development, such an overlap is very interesting because it indicates when the development of a robot may be economically feasible.

## 6 Conclusion

The results of the case study comprise a huge data set of current work processes marked up in computationally searchable ways to facilitate the identification of current tasks that are carried out repetitively across departments of the same large and complex institution. The results present open problem spaces for which numerous different possible solutions can be developed without having biased the data elicitation from the perspective of technical feasibility. Furthermore, the way in which needs and challenges that may be addressed by means of robots or other kinds of technology have been identified, preserves the rich social and institutional contexts in which they occur and that need to be taken into account during robot development. Use case development based on large-scale ethnographic observation thus allows a discussion

of robots in health-care applications along the lines of social, societal, ethical and environmental values.

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## A Examples of observed workflows

In the following, we provide two concrete examples of the reports written based on the observation of work flows. The reports were originally written in Danish and were translated for the current publication. In addition to the report proper, the observers provided a general description of their day, potentially additional observations they made at the ward and technical terms that may be specific to a ward.

### A.1 Observed workflow at the Department of Haematology

**Table 2:** Report number 14, table number 6 from evening observation at the Department of Hospital and Cleaning service. The corresponding categorization of this process is provided in Figure 2.

<i>Table number: 14</i>	
<i>Where do you observe?</i>	Patient room at the Department of Haematology
<i>Who is observed?</i>	Nurse
<i>Observed activity</i>	Change patient position
<i>Are additional people involved</i>	Patient and colleague
<i>What is its duration?</i>	2-10 min
<i>Context</i>	To avoid soreness, the patient is moved into a different position in the bed
<i>Describe the activity</i>	<p><b>Move the patient up the in the bed</b></p> <p>With a remote control which is attached to the guard rail the bed is raised to a good working height. The headboard of the bed is lowered to be in line with the rest of the bed. The patient is asked to bend the legs and to place his heels on the mattress. Then the patient is asked to push with both legs against the bottom of the bed to move himself upwards. However, the patient does not have the strength to do so, and so the nurse leaves the scene to get a colleague.</p> <p>The nurses position themselves at the opposite sides of the headboard and drag the bed sheet upwards so that the patient is moved up in the bed.</p> <p><b>Decompression of the heels</b></p> <p>The nurse places a pillow under patient's ankles to decompress the heels. This is done by lifting the legs with one hand and placing the pillow with the other.</p> <p><b>Side positioning</b></p> <p>The nurse leaves to pick up a long pillow from the storage. She closes the door to the patient's room and guides the patient to hold onto the left guard rail with his right hand. The nurse pulls on the right side of the sheet close to the patient's shoulder and behind so that he rolls around. She places the pillow under the right side of the patient. She asks the patient to lean back and corrects the position of the pillow to ensure that he is lying comfortably.</p>
<i>Tasks made at the same time</i>	-
<i>When is the task accomplished?</i>	-
<i>Stress level? 1-5</i>	2
<i>Crowdedness? 1-5</i>	3
<i>The frequency of the activity (observed staff)?</i>	3
<i>The frequency of the activity (department)?</i>	10
<i>Is it important that the task is done now, and why?</i>	No, but it is important that patients' positions are changed frequently
<i>Are special competences required?</i>	Yes, knowledge about patient positioning
<i>Images?</i>	None

## A.2 Observed workflow at the Department for Cleaning and Hospital Service

**Table 3:** Report number 12, table number 2 from evening observation at the Department of Cleaning and Hospital Service. The corresponding categorization of this process is provided in Figure 2. The frequency of 99 has been used to indicate that the observer could not specify the frequency of this workflow precisely but that the workflow is performed at least several times per day.

<i>Table number: 2</i>	
<i>Where do you observe?</i>	Hospital corridor
<i>Who is observed?</i>	Service assistant
<i>Observed activity</i>	Transport of beds with and without patient
<i>Are additional people involved</i>	None
<i>What is its duration?</i>	10 min
<i>Context</i>	Bed transport from a department to the storage, a second department or to an examination room
<i>Describe the activity</i>	<p>The service assistant walked over to the department. The room number had not been mentioned in the request, and thus the service assistant looked around for the bed in the department.</p> <p>The bed can be unlocked by stepping on a stick near the wheel. The lock can be activated completely or partly for avoiding wheel rotation, which makes it easier to move the bed straight-ahead.</p> <p>With the remote control, placed at the side of the bed, the bed can be moved up- and downwards.</p> <p>The assistant pulls the bed away from the wall holding onto the long side of the bed.</p> <p>On the headboard of one bed, a roll of paper had been placed to cover the bed during examinations. The paper was rolled out, so the service assistant rolled it back up and fixated it by crumpling up the end.</p> <p>The assistant pushes the bed by the headboard along the hospital corridor. In one instant, the remote control fell off the bed since many items were placed on both sides of the corridor, making it necessary to steer the bed from left to right and back. It was frequently necessary to move obstacle, which were placed in the corridor, away.</p> <p>The service assistant also stopped repeatedly for oncoming traffic.</p> <p>Narrow corners at departments caused the service assistant to turn the bed by significantly pushing more with one arm and by moving the bed back and forth.</p> <p>To slow down the bed, the service assistant leaned backwards and pulled on the headboard.</p> <p>Normally the service assistant orients herself at the department-dependent wall color in the basement to find the way. Once she lost her way and walked in circles.</p> <p>When a patient is transported to an examination, the service assistance asks the staff how long the examination will take. If the examination is completed within 10 minutes, she waits in the department and returns the patient right away.</p> <p>Once a patient was returned without an examination due to the condition of the patient, this was noted as an unsuccessful transport.</p>
<i>Tasks made at the same time</i>	None
<i>When is the task accomplished?</i>	During the shift
<i>Stress level? 1-5</i>	3
<i>Crowdedness? 1-5</i>	4 (some corridors was more packed than others)
<i>The frequency of the activity (observed staff)?</i>	6
<i>The frequency of the activity (department)?</i>	99
<i>Is it important that the task is done now, and why?</i>	No
<i>Are special competences required?</i>	No
<i>Images?</i>	-

### A.3 Observed workflow at the Department of Cardiology

**Table 4:** Report number 47, table number 12 from evening observation at the Department of Cardiology. The corresponding categorization of this process is provided in Figure 2.

<i>Table number: 12</i>	
<i>Where do you observe?</i>	between the hall and the examination room
<i>Who is observed?</i>	Nurse
<i>Observed activity</i>	Transport of patient in bed
<i>Are additional people involved</i>	A nurse, the patient and a relative
<i>What is its duration?</i>	5 min
<i>Context</i>	The patient is admitted to a different department, and the nurse wants to avoid moving her to the examination table.
<i>Describe the activity</i>	<ul style="list-style-type: none"> <li>– The patient lays in a hospital bed in the corridor, and the relative sits near the patient's head.</li> <li>– The nurse moves an examination table out of the examination room and into the corridor (to make space for the bed).</li> <li>– The nurse walks towards the bed and shakes hands with the patient and relative and informs them about the room of the examination.</li> <li>– Then the nurse moves the bed from the headboard of the nurse; the relative first moves the chair out of the way and thereafter controls the foot end of the bed.</li> <li>– To ensure that the bed is positioned correctly in the examination room, the bed is turned around in the corridor. The foot of the bed bumps against the wall since the corridor is very narrow.</li> <li>– The nurse stands in the examination room and pushes the bed back and forth to get it through the door. The door is narrow for this type of hospital bed. After some minutes, she manages to get the bed through the door.</li> </ul> <p style="text-align: center;">This type of bed is big and heavy especially in relation to the 2-meter wide corridor.</p>
<i>Tasks made at the same time</i>	Talk with the relative, patient and a doctor.
<i>When is the task accomplished?</i>	Morning
<i>Stress level? 1-5</i>	1
<i>Crowdedness? 1-5</i>	4
<i>The frequency of the activity (observed staff)?</i>	1
<i>The frequency of the activity (department)?</i>	3-5, when a admitted bed laying patient are examined
<i>Is it important that the task is done now, and why?</i>	Yes
<i>Are special competences required?</i>	No
<i>Images?</i>	-