Service Robotics in Healthcare: A Perspective for Information Systems Researchers?

Research-in-Progress

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Abstract

Recent advances in electronics and telecommunication have paved the way for service robots to enter the clinical world. While service robotics has long been a core research theme in computer science and other engineering-related fields, it has attracted little interest of Information Systems (IS) researchers so far. We argue that service robotics represents an interesting area of investigation, especially for healthcare, since current research lacks a thorough examination of socio-technical problems and contextual influencing factors. This study identifies current research thrusts and delineates possible areas for theoretical, empirical, or design-oriented research for IS scholars. By means of a systematic literature review, we explore the current use, users, and utility of service robots in healthcare. Based on these findings, we suggest research topics that have the potential to be of practical significance. Our aim is to make substantive steps towards establishing service robotics as new research theme in information systems research.

Keywords: Healthcare information technology, hospitals, service robotics, research gaps

Introduction

Recent years have seen a proliferation of publications related to research on service robotics. Advances in electronics and telecommunication have paved the way for robots to move out of industrial contexts (e.g. assembling or welding robots) into our everyday life contexts. Various fast rising demands in society, such as the aging population and the lack of sufficient qualified caregivers, have especially favored their adoption for the support of health services. Examples are service robots with automated navigation abilities that perform transportation services at a hospital or pharmaceutical dispensing robots that support hospital staff in issuing medications (Barrett et al. 2012).

Prior research on service robotics in healthcare has shown that there is still a considerable long list of issues and challenges to be solved. For instance, Pineau et al. (2003) stress out the complexity of the tasks and limitations of sensors which jeopardize the performance of robots. Kuo et al. (2008) highlight obstacles related to the software architecture because of the proprietary design of navigation, localization, speech recognition and other functionalities of robots. Most recent studies also emphasize issues regarding the acceptance and social intelligence of robots (Broadbent et al. 2009).

In this sense, we believe that issues related to service robotics are not just technical, but significantly rather socio-technical (Anderson 2007) and economical (Lapointe et al. 2011). Albeit most work on service robotics suppresses the context of its application, this is of major importance particularly for the healthcare domain (Chiasson and Davidson 2004).

However, the purpose of this study is not to consolidate or challenge the credibility of the substantial research on service robotics that has been conducted in computer science and other fields. Instead, it is our goal to briefly summarize what we currently know about service robotics in the healthcare domain in order to delineate a trajectory of or themes for investigating these artifacts from an Information Systems (IS) perspective.

As service robotics are a socio-technical phenomenon, the artifact, or more precisely the robot, is always embedded in a social context (Orlikowski and Iacono 2001). In IS research, the increased service-orientation of artifacts has led to a higher significance of the social aspects, e.g. the user (Iivari et al. 2010). Therefore, our study focuses on use, user and utility of service robots and thus accounts for the increasing importance of the user, his usage scenarios and respective value aspects (Brenner et al. 2014). We hope to set an agenda that expands current Health Information Technology (HIT) research and that identifies fruitful areas of work in this important arena. Our contribution, hence, lies in broadening the current understanding of service robotics in the domain of healthcare and the discovery of IS-related research opportunities.

The remainder of this manuscript is structured as follows: In the next section, we set the boundary conditions by defining our understanding of the term “service robotics”. Failure to do so effectively would lead to the criticism that our research could include almost all work on artificial intelligence and would be completely disconnected with the core topics of the IS discipline. In the subsequent section we present the results of a systematic literature review and briefly summarize what we currently know about service robotics applied in healthcare. Based on these prior findings we derive areas of research that could be of major interest for IS researchers. We conclude the paper by discussing the most relevant implications as to the research agenda of scholars interested in HIT and context-specific research in the healthcare domain.

Framing Service Robotics: Scope of Study

What are service robots? It is important to mention that no commonly accepted definition exists so far. The term “service robot” implies that these robots are able to perform tasks in an unconstrained, human-centered environment (Haidegger et al. 2013). More precisely, the International Standardization Organization (2014) defines the term “service robot” as “a robot that performs useful tasks for humans or equipment, excluding industrial automation applications”, whereas the International Federation of Robotics (2014) stresses the aspect of autonomy in its definition: “A service robot is a robot which operates semi- or fully autonomously to perform services useful to the well-being of humans and equipment, excluding manufacturing operations.” Both the International Federation of Robotics and the

International Standardization Organization distinguish between personal and professional service robots. In this paper we adopt the conception of professional service robots which are used for commercial tasks, usually operated by a properly trained operator (International Federation of Robotics 2014).

According to existing ontologies for robotics, service robots can be further categorized into different domains (Prestes et al. 2013). We border the focus of our study to the healthcare domain which broadly can be subdivided in a "clinical world" and a "consumer health world" (Mettler and Raptis 2012). In this paper, however, we emphasize the use of service robots in clinical settings only, since the purpose (health-related or not) of different consumer appliances frequently cannot be separated accurately.

Hence, three important aspects delimit the scope of our study:

(i) A service robot presupposes a degree of autonomy, meaning that actions and tasks are partially or fully performed without human intervention.

(ii) The aforementioned actions and tasks refer to activities for producing (mostly intangible, automated, and personalized) services for humans; therefore excluding manufacturing operations.

(iii) These activities are performed in a professional healthcare area or, more precisely, in the clinical support context.

Following this definition, a service robot can be characterized as any machinery or device in the clinical setting that is able to perform tasks, either partially or fully autonomous, in order to produce a service which is to some extent useful to a human; for instance, cleaning of floors, or delivery and transport of goods. However, "utility" must not necessarily be restricted towards a utilitarian purpose. Service robots can also give hedonic value to humans, such as improving psychological enrichment and enjoyment of patients (Sullins 2008).

Method

Literature Review

In order to inform about and enable hospital information officers to better understand the potential of service robots in clinical contexts, we have conducted several cross sectional document studies and field observations in two countries, Norway and Switzerland. This paper reports on the findings from the literature search and review performed according to Webster and Watson (2002) that we have conducted upfront to know more about service robots and their role in the big picture of HIT research.

To find out what we know about service robotics in clinical contexts, that are of relevance to IS-research, we performed a systematic literature search, in the database portal that we deemed as likely to cover the most relevant subjects (cf. Table 1). For this, we used EBSCOhost, which searches several databases for interdisciplinary journal articles.

In addition, a more refined search in ProQuest was conducted in order to search for possible secondary papers not found in the first search. In the third and last search we did an author/theme based forward search. In total we found 473 articles, reduced for duplicate findings. We used truncations like 'robot*' and '*health* (OR) hospital*' in the two first searches, to cover the area of 'service robotics' in clinical support systems; the Boolean operator 'OR' giving 'e-health', 'healthcare' and 'hospital'/'hospitals'.

Inclusion criteria

As our search was concerned with the role of service robotics in clinical support systems, we excluded articles that dealt with surgical robotics and robotics in rehabilitation. Also articles solely dedicated to technical design or feasibility were excluded, as we wanted to explore the socio-technical aspects of robotics, the adoption of this technology for support and logistics in hospitals, its usage, users and utility. A substantial amount of literature about robotics is engineering-related, such as for example the use of magnetic fields for penetrating line-of-sight obstructions (Prigge 2004). Although left outside the scope of this review, a study of this kind of literature can inform us about technological changes and opportunities for service- and workflow improvements to come.

From the rest of the articles, we could elicit knowledge relevant to our area of concern. Most articles included were scholarly, but due to the "newness" of this area, we included six additional articles from professional press and magazines, and two from a newspaper or online newsletter, all found in the EBSCOhost search.

In our first search we found an article by (Rossetti et al. 2000) that had a theme that fitted especially well with our area of concern. Searching for articles from the same group of researchers, we found an earlier conference proceedings article of approximately the same theme that was much cited (34 times). After the third search we screened these citing articles and found an additional six relevant articles.

Screening

The screening done by one researcher was reviewed and revised by the other researchers, independently of the first. Discrepancies were discussed until agreement about inclusion / exclusion based on our criteria was reached. Thus, we elicited 33 articles containing relevant knowledge.

Table 1. Search Strategy

Date	Source	Search string	In	Comment	F1	F2	F3
03/14	EBSCOhost all databases	robot* AND (*health* OR hospital*)	title, abstract or keywords		110	87	20
03/14	ABI/Inform (ProQuest), all databases	robot* AND (*health* OR hospital*) NOT surgery	title, abstract or keywords	only scholarly journals	416	352	7
04/14	Rossetti et al (1998)			forward search		34	6
SUM						**473**	**33**

Note: F1 = Total number of articles, F2 = Articles reduced for duplicates, F3 = Articles containing relevant knowledge for this study.

Method of analysis

The main new findings we aggregated into concepts of knowledge (cf. Table 2 in the Appendix). As service robots are as much social systems as they are machines, it is important to understand the social dimensions that accompany the service robot (Avgerou 2000). In this context, the user has the role of a social actor calling for a user-centered analysis approach (Lamb and Kling 2003). After starting with the antecedents of service robotics we therefore group the findings of our literature review into the main categories of use, users and utility (Brenner et al. 2014).

Findings – What we know

Our overall impression of the literature is that it describes a technology-induced innovation that is still in its very early stages, although the core technology itself is known since the mid 1980's.

Antecedents of Use

Literature has shown little of the antecedents of robotics in clinical health support, but points to the need. The hospital staff's perception of workload and stress is a positive determinant for motivating the shift to robot couriers (Mendell et al. 1991). And the need for automation may be imminent.

> "Within 10-15 years [from 2008], every third student [in Sweden] has to choose occupation within the health care sector to obtain the current personal level, due to the aging population and retirement within the health service sector" (Göransson et al. 2008).

Use

Niechwiadowicz and Kahn (2008) compare the functionality of robots from different vendors for transport (carry, tow) and logistics (task scheduling, automated elevator service). Also some new robots under development are examined for functionality.

Current use-cases for clinical service robotics

Using robotics to optimize inventory is a growing use-case. In addition to serving "delivery routes", robots track inventory on demand, using radio frequency identification (RFID) tags on inventory. Staff can dispatch the robots using touch screens (Institute of Industrial Engineers 2007). Pharmacy robots gave a significant reduction in medication errors (Bepko Jr et al. 2009). For instance, robotic drawers reduce errors in medication, identifying staff by fingerprint (Wray 2012).

Robotics in US hospitals

In 2012 close to a thousand "blue collared" robots were used in US hospitals. Estimates are that in five years, there will be 10 times the number of robots deployed in hospitals than there are today. Leasing is used as a business model in US:

> “The El Camino hospital entered into a five-year lease with Aethon Inc. for the 20 robots, which was less than half as expensive as hiring staff, according to management” (Hay 2012).

Transport is not a very welcome task for most staff, especially nurses, since they were mostly hired for other purposes. So in general they often welcome labor saving devices like service robots (American Health Consultants 1999).

Users

The user-centric approach proposed by Brenner et al. (2014) is also reflected by our literature review, where we found evidence about roles and attitudes of some user groups, which are discussed in the following.

The need for staff involvement

Several studies indicate a strong need for staff education, training and involvement. Exposure to new technology alone does not comprise to a positive attitude towards robotic technology (Kristoffersson et al. 2011). Staff must be prepared and technology readiness must be established (Peronard 2013). The whole staff of the hospital must be educated on how to deal with autonomous service robots (Kirschling et al. 2009). So, developers of the technology and its users must collaborate (Minifie 1989). User tests should not only include primary users but also secondary users and bystanders (Huttenrauch et al. 2004).

Attitudes and viewpoints towards robotic systems

Ljungblad et al. (2012) describe how a transport robot was perceived in different ways simultaneously by different groups (staff, visitors etc.). Attitudes among students towards robotics in healthcare vary from negative towards robots in care, to positive towards robots in service and support (Göransson et al. 2008).

There have also been critical voices in the press, such as for instance in the UK:

> “[...] Mungo Smith, director of Maap Architects, described the robots as ‘boys' toys’ and claimed they are ‘the wrong answer to the wrong question’. ‘Why would we need to use robots in the first place ?’ he asked. ‘Because hospitals are too big. They should be built small, local and accessible.’ [...]" (Ancell and Crump 2007).

Issues with robotics may not be reported in the UK, due to liability laws, whilst for example the German press in general is positive (Laryionava and Gross 2012).

Utility

Studies show a good return-on-investment (ROI) on robot couriers: 12%, with increased delivery stability, and decreased delivery time. Prerequisite for achieving this is proper training and acceptance of staff (Rossetti et al. 2000). Jacobson et al (2006) cites the Rossetti et al. (1998) study as an example for using simulation techniques for measuring the cost savings effect of robotics.

Assessing new technologies

Assessment tools for health technology have been developed that screen several aspects for risk and quality (Morilla-Bachs and Gutierrez-Moreno 2012).

The use of robotics in inventory management is thought to provide benefits. Measuring the quantitative and qualitative effects of the introduction of service robotics can give conflicting measurements (Rossetti et al. 2008). The Analytic Hierarchy Process (AHP, often used in supply chain in health settings, according to the authors) was used in one particular case study to address these trade-offs, decomposing objectives into sub-objectives to get better comparisons.

What We Need to Know

The literature review reveals certain knowledge regarding use, users and utility of service robotics, however deeper knowledge is required in the different areas as well as in their combinations. Since socio-technical phenomena are complex in nature and have far reaching implications (Brenner et al. 2014), questions regarding, for example, the compatibility of service robotics and related viable business models are not trivial. Besides the above introduced research fields of use, users and utility we see a fourth area where further research is needed from an information systems perspective: the design of the artifact, the robot, itself.

Use

Although, our literature review already revealed some research regarding the use of service robotics in hospitals (Bepko Jr et al. 2009; Wray 2012), we see a need for further knowledge regarding different use cases and the implications for the hospital organization when employing service robotics. From interviews with hospital professionals we know that potential users still don't understand the full potential.

Possible use cases

In general, there are certainly many fields of application for service robotics. However, the question arises which use cases would be supported in a hospital context. Do hospitals rather like robots to be out of the patients' sight or is robot-patient contact even desired? What are indicators determining when it is useful to introduce a service robot (e.g. number of times a service is executed per day; costs of alternative solution; ease of service robot implementation)?

Our literature review indicates that the use of robotics in monitoring and therapeutic roles towards patients is believed to be a growing area (Bzura et al. 2012). Tests are performed on robots as teachers for patients with cognitive disorders, for tasks as brushing teeth. Also in clinical support systems many new opportunities for automation is eminent. For instance, many of the pre-analytical duties of laboratories that today are dominantly manual, can predictively be automated using robotics (Friess et al. 2003). The results can be good. The use of robots in inventory has in some cases (e.g. infusion pumps) cut the need for inventory in half (Hamblen 2008).

Process and System Compatibility

When introducing service robotics into the hospital, one has to keep in mind that the tasks and processes supported by the robot are not independent but have interfaces to the existing hospital systems and processes. How much integration is needed in order to fully leverage the potential of service robotics while at the same time keeping complexity considerations in mind? For example, a service robot with an interface to the hospitals IT systems would be more than just a mean of transportation but would also be able to track inventory, support the managing department etc. (Institute of Industrial Engineers 2007). However, integrating the robot into the whole application landscape might be very complex due to customized software and thus very expensive when it comes to the introduction of new software releases.

Users

Regarding the users of service robots, still unanswered questions are “Who are the ‘real’ users?” and “How does a service robot ‘fit’ into existing social systems?”

User groups

Even when focusing on hospitals, there is not one uniform user. First of all, there are different kinds of hospitals that differ in size, number of departments, employees and patients, etc. Second, even within one hospital there are different kinds of users depending on the service robotics’ use cases. For example, a service robot employed in an inventory context has logistic staff as users, as well as controllers who use the data of the robot to manage the hospital. When used in patient care, the users are nurses, patients and doctors. Moreover, users can also be grouped according to their attitudes towards service robotics, e.g. when Mantzana et al. (2007) categorized healthcare actors regarding their IS adoption, he identified human and organizational acceptors, providers, controllers and supporters.

Social Compatibility

Service robots must not only be compatible with existing processes and systems but also with attitudes and values present in the hospital context. Different user groups might have different values that could act as a driver or inhibitor for the introduction of service robotics.

Our literature review also showed the possibilities of changes in the hospital hierarchy which still need to be researched. Oborn et al. (2011) state that the sociological role of robots is still poorly understood, for instance, in terms of a “service logic”. The new technology can make shifts in power and change the roles between professions, often in unforeseen ways. Operators of the robots take on a new role as leading the procedures (in treatment, but also possible in logistics).

Utility

Utility can be specified in different ways and has to be considered from the different stakeholders’ perspective. Hence, we see the need for knowledge regarding the definition of utility in the different contexts as well as regarding viable business models that build on the relevant utility dimension(s).

Relevant utility dimension(s)

Depending on the way service robots are used in hospitals, for example as mere transport vehicles or integrated in existing systems and processes, there are different kinds of utility that can be attaint. The questions that still need to be answered are: Where do the different kinds of users see the advantage of service robotics? What is their relevant utility dimension (e.g. cost cutting due to reduction in workforce, stable processes, increase in control)? In case more than one utility dimension is pursued, there might be the problem of conflicting goals when there is a tradeoff between different utility dimensions.

Business models

Veit et al. (2014) stress the importance of understanding, explaining, predicting and designing business models in the IS context. Besides providing utility for the user, also utility aspects of other stakeholders need to be addressed, for example the seller of service robotics has to benefit sufficiently to ensure a viable business opportunity for him. This entails business model related questions, for example: Based on the relevant utility dimension what would be an adequate value proposition for each user group?

Moreover, there are different possibilities regarding the revenue model applicable for service robotics. Our literature review revealed that in the United States the leasing concept has been introduced (Hay 2012). If this is also an option for hospitals outside the US or if other revenue models like “pay-per-use” or the classical purchase is favored, is a field for future research.

Artifact

In IS research, the IT artifact should not be taken for granted, but is required to be explicitly theorized (Orlikowski and Iacono 2001). As IT artifacts are always embedded in the setting of use, users and utility, there is also a need for research regarding the design of the artifact itself and possible consequences of the design choices.

Artifact design

Depending on the use, users and utility considerations different artifact designs might be adequate. For example, if the service robot should have direct contact with patients or visitors, the robot should not look intimidating. In case the robot would serve as a mere transportation vehicle that would only be used underground, the design could certainly be different. Identifying the design requirements for the different situations is still yet to be researched.

Consequences of artifact design

One has to keep in mind that the design of a service robot might have consequences. On the one hand a certain design might have a direct effect on attitudes towards the robot itself. On the other hand the artifact design might leading to less obvious consequences: Our literature review pointed out, that also new ethical questions may arise:

> “As robots become more "human", or perform as proxies for humans, should they be treated with some respect?” (Shatzer 2013).

Arguably, the robots should be seen to inherit the respect needed to perform their tasks, from the important and time-critical missions they accomplish, and from their supervisors. The esthetic design of the robots can help accomplish that; e.g. indicate with colors, light, sound or other means the free zone needed around the robot.

Conclusion and Future Work

The intention of this study was to provide a deeper understanding of and motivate researchers for broader investigations in the area of service robotics. Due to an increased need for multidisciplinary and contextually rich research results (Chiasson and Davidson 2004), we believe that this is of particular importance for this domain. Since prior research only scratched the surface while investigating use, users, and utility of service robots in healthcare, there is still much to explore for IS researchers. The future research themes proposed by this study are somewhat nuanced and non-exhaustive, but they certainly introduce important directions for continued work. It is important to note once more, that we do not want to derogate the usefulness of previous research of other fields. Significantly, rather than recognizing service robotics as pure technological research theme, our study calls for additional research dealing with socio-technical challenges. As robots in our study are not in an industrial but in a service context, this increases the significance of the social aspects even more. Only by understanding the users, use scenarios and the associated utility of service robots, socio-technical challenges can be solved and the full value of robotics in healthcare can be realized.

Our own future research in this area will primarily focus on better understanding user perceptions, expectations, and intentions towards service robotics use in healthcare organizations. Specifically, we want to identify a typology of health service robotics users in hospitals.

Based on a detailed comprehension of users and their needs, the next step in our research agenda is to explore different use cases of service robotics in distinct healthcare organizations (e.g. hospital, nursing home, rehabilitation facility) as well as examine users’ reactions on distinct application scenarios. Finally, we want also to investigate possible ways how to effectively measure “utility” or “usefulness” for specific use cases and specific user groups. This will particularly be of help to hospital information managers who possibly tinker with the idea of implementing service robotics in their organization.

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Appendix

Table 2. Concept-centric literature review

No.	*Source*	*Antecedents*	*Use*	*Users*	*Utility*
1	Akire et al. 2012		●		
2	American Health Consultants 1999		●		
3	Ancell and Crump 2007			●	
4	Bepko Jr et al. 2009		●		
5	Broadbent et al. 2009				●
6	Bzura et al. 2012		●		
7	Deery 1997				●
8	Etherton and Collins 1990			●	
9	Friess et al. 2003		●		
10	Göransson et al. 2008	●		●	
11	Hamblen 2008				●
12	Hay 2012		●		
13	Huttenrauch et al. 2004			●	
14	Institute of Industrial Engineers 2007		●		
15	Jacobson et al. 2006				●
16	Kirschling et al. 2009			●	
17	Kristoffersson et al. 2011			●	
18	Laryionava and Gross 2012			●	
19	Ljungblad et al. 2012			●	
21	Mendell et al. 1991	●			
22	Minifie 1989			●	
23	Nejat et al. 2009				●
24	Niechwiadowicz and Khan 2008				●
25	Oborn et al. 2011			●	
26	Oestreicher and Eklundh 2006	●			
27	Peronard 2013			●	
28	Rossetti et al. 2000				●
20	Rossetti et al. 2008	●			●
29	Sampietro-Colom et al. 2012				●
30	Sharkey and Sharkey 2012	●			
31	Shatzer 2013	●			
32	Smith 2008				●
33	Wray 2012		●		