Indoor Smart Wheelchair: Systematic Mapping

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Abstract. Wheelchair are designed to enhance a patient's personal mobility. It should help users to engage as much as possible in events. Therefore, rather than having a negative impact on its health or safety, the consumer should be able to live more active lives. Researchers have constantly worked to provide the patient with the best tool. At the time, patients had the option to use a wheelchair only, but now exoskeletons were introduced and proved as planned to have been successful. However, the use of wheelchair have never been brought down, in fact, the wheelchair that we all known are evolving into something fresh and new due to the effort of researchers applying new technology. Since a new idea for wheelchairs has been proposed, we conducted a systematic mapping study (SMS) on features introduced by researchers on wheelchairs. We identified 41 papers coming from conferences, symposium, workshops and journals. A total of 13 features exist in wheelchairs are identified. We present a qualitative analysis of the wheelchair, an overview on features for wheelchairs.

1. Introduction
The purpose of wheelchair is to provide mobility for handicapped and elderly people or any patient who are having disabilities. In these circumstances, the disable people need assistance or a helper in assisting their daily routine. Hence, a wheelchair becomes a necessity for them. The wheelchair was first seen in 1595 and was made by an unknown inventor for Philip II, Spain. Through the years until now, the wheelchair has been evolving along with our current technology.

Several research works suggest the creation of various standard solutions such as joystick controlled wheelchair, hand gestures, and wheelchair controlled android [1]. Presently, joystick is the basic control system for disabled people's electronic wheelchairs [2]. Hand gesture-based wheelchair is also available in present where user can use their hand gesture to control the wheelchair's movement. Thus, the common wheelchair is now a smart wheelchair. However, it is important to address the mobility of the wheelchair due to different environment or crowded indoor space [3]. With the technology installed, the wheelchair will provide more comfortable movement and become convenient to the users, thus, suitable for indoors.

2. Related works
Our paper is a tertiary study follows the SMS guideline. In this section, we mentioned other published tertiary studies related to our own. There are a few publication papers that are related to ours and worth mentioning.

On 2005, Richard C. Simpson conducted a systematic literature review on smart wheelchairs. He identified a total of 47 papers that relates to his study. Parameter extracted from the papers are tabulated in terms of operating mode and the result shows that there is a total of 11 mode exist in the

research area. He concluded that the significant technical issue occur in the research area is the cost versus accuracy [2]. The cost is high, and it is not ready for commercial, claimed by the author.

On 2017, Andrea et al have conducted a systematic review on identifying power wheelchairs and its mechanism. They also present data comparing its capabilities in terms of step climbing and standard wheelchair functions. Based on the findings, they found that all devices are not inconsistent with traditional power wheelchairs in order to allow object traversal, but the slow speeds and limited wheel diameter of some designs make them only moderately successful in the basic field of efficient ground-level transport [3]. They advised to apply a performance test methods more comprehensive than the International Organization for Standards (ISO) in measuring the abilities of advanced wheelchairs with step-climbing and other environment-negotiating features [3].

Lastly, on 2011 [4] carried out a systematic literature review to assess the quality of evidence on the impact of cross-paths on manual propulsion by wheelchairs. Their goal were to identify the optimal design of crossings with less negative effects towards wheelchair users [4]. A total of 52 subject-related articles were reviewed and the results showed that most studies concluded that it is more difficult crossing a cross path than moving on a flat surface in a manual wheelchair.

3. Research method

The following in Figure 1 demonstrates a systematic process for conducting SMS to resolve all the research questions mentioned in wheelchair research area. The systematic and structured method was inspired by [5] and [6].

(a)   (b)
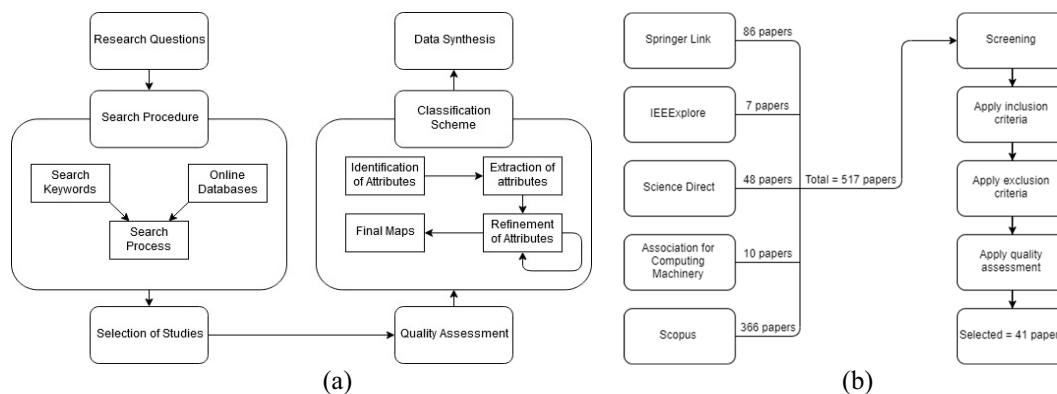
Figure 1. Research process: (a) Structured SMS method; (b) Search result.

The structured method of the research process (Figure 1(a)) are followed from Muhammad Uzair Khan's [7]. This SMS aims to comprehend and review papers that are related to wheelchairs. Keep in mind that the objective of the SMS is to assist other researchers in visualizing the research gap. The writers also want to investigate the features and control interface used in wheelchairs. To achieve the objectives, three research-related questions have been formulated as illustrated in Table 1.

Table 1. Research questions and descriptions

Research questions	RQ statement	Description
RQ 1	Which are the most popular feature applied in wheelchair?	This research questions aims to identify the most areas covered in test case selection
RQ 2	What are the most popular controller build for wheelchairs?	This research questions aims to identify the most popular controller build in wheelchairs

A search a search procedure is essential in each SMS to ensure the broadness of the study selected. The procedure is consist of search strings, online databases, search process and selection of studies.

All search has been done by using this search query, "Smart wheelchair" and "Indoor". We searched for the related publications in a total of five online repositories. These include: Springer Link, ACM Digital Library, IEEExplore, Science Direct and Scopus. The search consists of the title, abstract and keywords of publications. Papers from all library (exclude Scopus) are likely to be redundant from result in Scopus.

Systematic search of databases for the identification of relevant studies is a key activity in a systematic mapping. Search keywords and online databases need to be presented. Keywords in each database are different depending on each style of representation in their databases. The search process took place when the keywords have entered the search bar in each database. The search result will belong to our investigation.

Initially, the search results from all online databases are approximately 517 papers in total. Then, the inclusion and exclusion criteria are applied for selecting the final papers. Applied criteria decreases the initial value from 517 papers to 41 papers. The criteria are as follows: (1) Paper must be published in English, (2) At least one research question must be answered, (3) Paper must be focusing on indoor smart wheelchairs and (4) Paper must have bibliographic information.

4. Result and discussion
In this section, we present our results and answer the research questions along with a discussion.

RQ 1. Which are the most popular feature applied in wheelchair?
To identify the most popular feature applied in smart wheelchair, we map a bubble chart that corresponds features as X-axis and number of papers as Y-axis, thus, Figure 2 and Figure 3 are presented. From the result we can deduced that obstacle avoidance has been popular since 1995 with a total of 37% from 41 papers. There are also 13 types of features that are applied in wheelchair. Location tracking is showing an improvement as the implementation of it have been increasing since it firstly known on 2004. It allows patient care or family to know the whereabouts of the current location of the wheelchair. Not only that, it also enables the wheelchair to generate path according to its history and sensors. Health monitoring is convincing even though it is still new. Obstacle avoidance module help to detect any obstacle directed towards itself and it will turns the wheelchair, thus, the wheelchair prevents the user from a head-on collision [8]. It is safe and independent mobility which is suitable for indoors. With this evidence, it indicates that obstacle avoidance has been trending by researchers.

RQ 2. What are the most popular control interface build for wheelchairs?
Traditionally, wheelchairs are push manually with user's strength only but nowadays, we have collected different kinds of interface for wheelchair movement. Based on Figure 4, joystick have proven to be popular as it covers the biggest numbers of paper published among the 41 papers and second place goes to head gesture and voice command. These interfaces bring new culture where users are able to move the wheelchair with only their head motion and speech command.
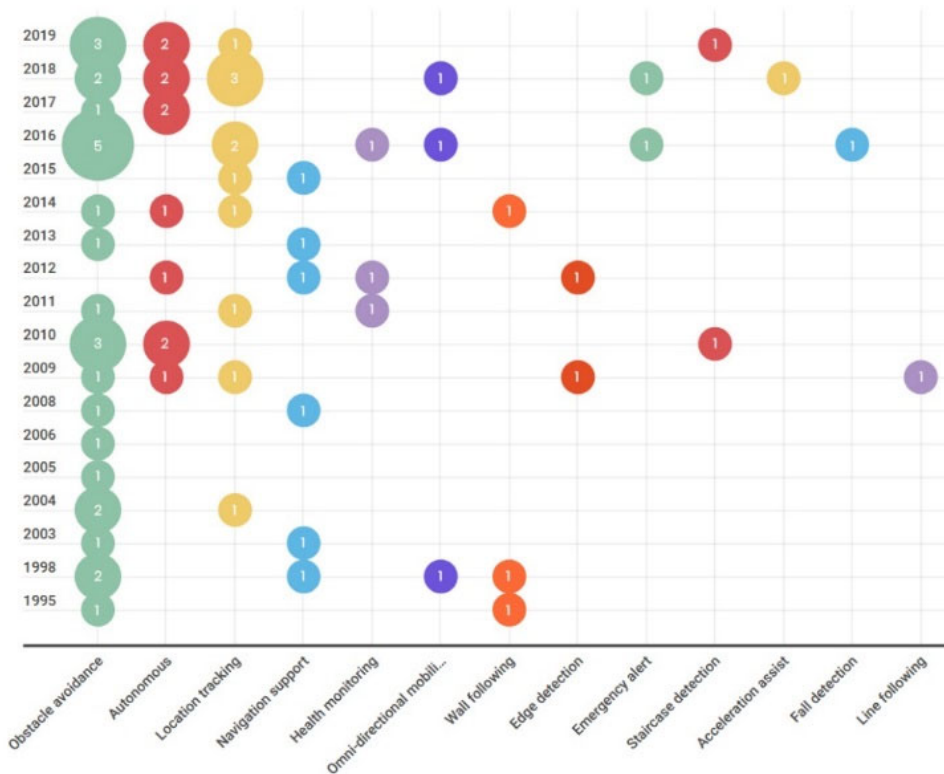
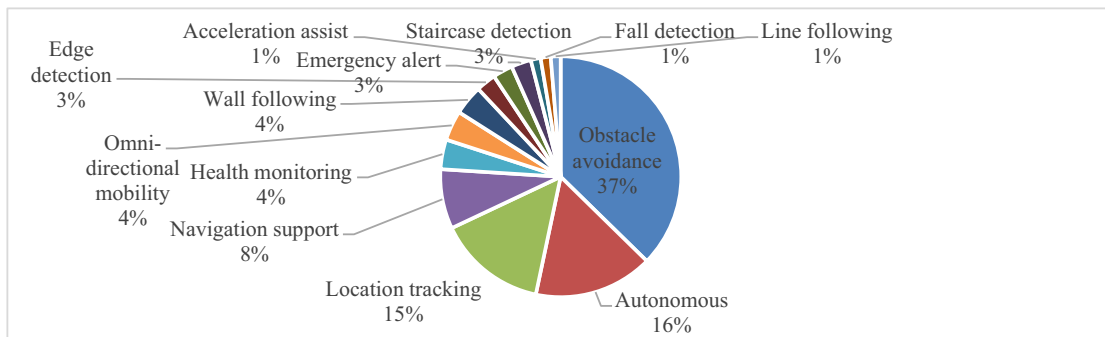Figure 2. Features applied in wheelchair within 1995 – 2019
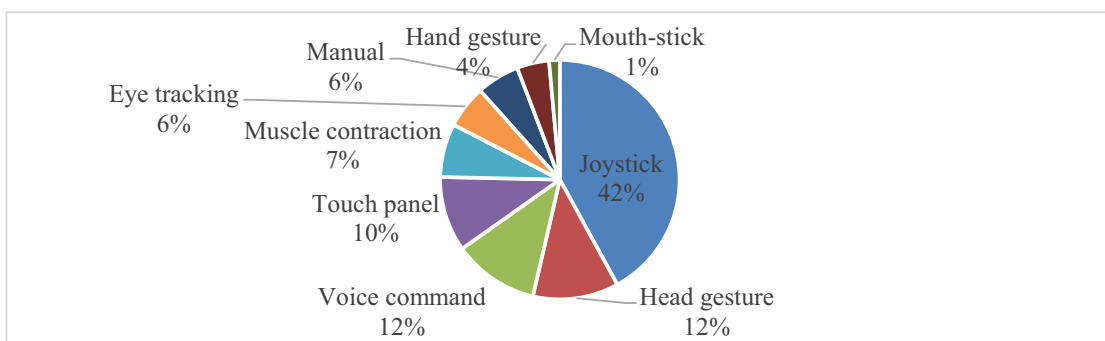

Figure 3. Percentage of wheelchair features

Figure 4. Percentage of wheelchair control interface

5. Conclusion

The paper presents an overview of existing research that has applied and investigated on the structure of wheelchair. Systematic mapping study is used to prove the research objectives. The study manages to prove obstacle avoidance and joystick as the most popular implementation on wheelchair's feature and control interface respectively. On top of that, among all the papers published, research on improving the current state of the wheelchair is mostly for general use, but there are some studies are specific to help the elderly or the disabled, such as [9]–[13].

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