User Requirements for a Robot Teleoperation system for General Medical Examination

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Abstract— **Thailand, as well as many other countries worldwide, is facing a shortage of medical staff. We purpose a solution to improve medical services in health centres: a robot teleoperation system to allow patients to consult with doctors from public hospitals, and for doctors to examine and make decisions about their required care. To develop such a system, a user-centred design (UCD) process is followed. Here we present an important first step in this process to establish user requirements for such a system. Hence, we have conducted a focus group with Thai medical staff from Banphaeo General Hospital and an online survey with potential patients. An online collaborative board has been setup to facilitate running the focus group virtually and provide an effective tool to gather data. A qualitative data is then analysed using a framework analysis. Based on this work, we present a list of user requirements for doctors, patients and assistants and discuss how the collected requirements can be transferred into technical specifications of the system. Our study found that communication among different user groups is the most important requirement.**

I. INTRODUCTION

The maldistribution of healthcare workers is common globally, for example, in England and Wales [16], southern Africa [24], and southeast Asia [17]. The shortages are even more critical in developing countries e.g., in Thailand, due to emigration of medical staff from developing to developed countries, and domestic migration from rural regions to urban centres since it provides better living standards, higher incomes, more social recognition and greater job satisfaction [29]. A survey in Thailand has shown that there are certain clear uneven distributions in medical personnel, especially physicians (Gini index = 0.433), by province. For physicians, nurses, and patient beds, approximately 39.6% of physicians, 25.8% of nurses, and 20.6% of patient beds are concentrated in the Bangkok Metropolis [21]. This is the main reason that we propose a robot teleoperation system to improve medical services in rural areas of Thailand.

To overcome the problem, one of the possible solutions is to use telemedicine system to make medical expertise available in rural areas where healthcare facilities are inadequate. It has been proven that remote examinations increase accessibility to health services, and patients spend less time waiting for consultation [3]. In order to develop the system, complex system requirements must be understood. This study aims to gather and analyze requirements and produce a set of design recommendations. Fig. 1 briefly demonstrates the robot teleoperation system. The use case proposed here is

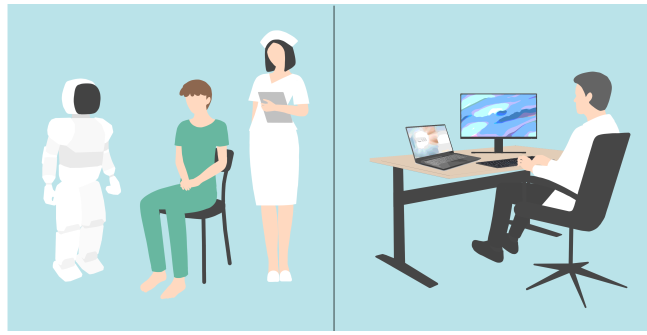

Fig. 1. Robot Teleoperation System: Patient's site (left) and Doctor's site (right)

that in a health centre (patient's site), healthcare assistants will help doctors examine patients using medical sensors which link to the robot teleoperation system. To successfully operate the robot teleoperation system, it is crucial to understand the requirements for all user groups, i.e., doctors, patients, and assistants. On a doctor's site, doctors will diagnose patients remotely using the information provided via the telepresence interface, give consultation to the patient, and make decisions about their required care. This would reduce the number of patients at public hospitals, saving time and costs for patients and hospitals. Moreover, such a system would facilitate social distancing, necessary in the case of a pandemic such as COVID-19 [28]. In addition, remote consultation would be useful when patients require secondary-care consultation after a referral from doctors or follow-up consultation for previous treatments (e.g. [5]).

Pepper[1], a humanoid robot, is a possible teleoperation platform that can be employed. It is well-developed, has form and function suited to social interaction, and has a well-documented software development kit (SDK) and open source integration with middleware such as Robot Operating System (ROS), a free, open-source middleware platform for robotics which facilitates easy development. Therefore, it has been introduced to the participants in the focus group as a possible platform for the robot teleoperation system. Multiple sensors and software stacks in the Pepper robot enhance a safe human-robot interaction, and therefore, it has been commonly used in medical research [36], [33]. Hence, a key component of the proposed program of study focuses on software development and testing to build user-friendly interfaces for assistants and doctors. It will be developed based on a user-centered design (UCD) process [22] to

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[1]https://www.softbankrobotics.com/emea/en/pepper

ensure that the system meets the user requirements.

This paper reports on requirement analysis from a focus group with Thai medical staff from Banphaeo General Hospital, Thailand and a follow-up patient survey. To collect the data, a focus group is conducted to know the typical steps of diagnosis and common ailments, and to define the requirements of a robot teleoperation system for doctors and assistants. Then, a survey with general people is done to obtain the requirements from patients' perspective. The paper is organized as follows. Section II presents the background and related works to the robot teleoperation system. The steps to gather the user requirements are described in Section III. In Section IV, the requirements for all user groups are listed. Discussion how the collected requirements can be transferred into technical specification is done in Section V. Conclusions and the potential for future works are included in Section VI.

II. BACKGROUND & RELATED WORK

Several kinds of telemedicine services have emerged over the last few years. There are teleoperation systems that can carry out minimal invasive surgery remotely [25], [32], perform ultrasound examination [3], [1], ophthalmology examination [19], [14], neurological examination [15], ear and oropharyngeal examinations [6], and physical examination with palpation [31]. In addition, remote consultation between general practitioners (GPs) in community hospitals and senior consultants in a specialist trauma centre had improved patient care greatly over a year since it avoided the transfer of 70 patients, representing an estimated cost saving of £65,000 [2]. Nevertheless, the focus of this remote consultation is slightly different from our study as it aims to facilitate communication between GPs and senior consultants, not between GPs and patients, and therefore, the types of information transferred in the telepresence system will be different.

In several other studies, it has been demonstrated that telepresence systems can be used to allow patients to have convenient access to general practitioners (GP) for remote consultation. Fatehi et al. [10] showed that patients with diabetes who were seen remotely by endocrinologists via videoconferencing were generally satisfied, despite the inability to perform physical examination. Nielson et al. [20] explored the use of telepresence robot for rehabilitation of a Parkinsonism patient and succeeded in performing a smooth and successful video-mediated consultation, preventing hospital readmissions while improving the patients' recovery. However, the limitations of both telepresence systems are the lack of medical features to provide better diagnosis, and no formalised requirement analysis has been conducted to understand what the end-users need.

The telemedicine system used in the United Kingdom, namely medicspot[2], allows patients to be remotely examined by a GP and collect any medicines at the pharmacy if needed. However, the limitation of medicspot is that the system has no physical but a virtual embodiment. It has been shown in multiple papers that the presence of a physical embodied robot facilitated more social interaction and provided more user engagement in people [34], [9], [27], [23]. The physical embodied robot is found to reduce the feeling of being far from the remote partner, and therefore, users are more likely to prefer physical over virtual embodied system. Hence, our proposal to use a robot teleoperation system for medical diagnosis as social interaction and patient engagement are vital for a successful diagnosis.

Carranza et al. [7], [8] developed Akibot, a telepresence robot with the integration of an otoscope, a stethoscope, and an ultrasound probe to improve the diagnostic capabilities for remote consultation. The results indicated that the end users were impressed by robot appearance, satisfied with the robot control, and thus, receiving a high System Usability Scale (SUS) score [4] of 82.5 over 100 points. Despite the users' satisfaction in Akibot, an activity-centred design (ACD) process is implemented in the study which will focus more on the task rather than the end-users. Hence, it is possible that users might not fully understand how to operate the system properly, taking longer time to adapt to the system and increasing the chances of causing accidents from misuse. Therefore, a user-centered design (UCD) process [22] is implemented in this study. It is an iterative design process used to design a system which focuses on what the end users need in each stages of the design process. UCD involves users throughout the design process, and hence creates highly usable and accessible products for them [30]. UCD is commonly used in the field of human-robot interaction and other design industries and it has been shown in multiple research papers (e.g. [12]) that it leads to a usable product that meets the end users' needs. In this paper, we present the first step in a UCD process which is the requirement analysis. The user requirements for doctors, patients, and assistants are considered for the implementation of a robot teleoperation system that allows patients to consult with doctors from a public hospital, and for doctors to examine patients remotely and make decisions about their required care. The following section describes the process of how the users requirements are analysed in such a system.

III. USER REQUIREMENTS ANALYSIS

In order to reach our end goal of a highly usable robot teleoperation system for medical diagnosis, we did a requirement analysis as a first step of the UCD process [22] by running a focus group with Thai medical staff and conducting an online survey with general people. This section provides details on the requirement analysis with the end-users.

A. *Focus group with Thai medical staff*

Four medical staff from Banphaeo General Hospital were recruited to the focus group as a group of 4-6 people is the ideal group size for a focus group [18]. All participants are male, in the age between 18 - 35 years, working as General Practitioners for less than a year. Every day, they need to examine patients several times, which could go up to more than 10 times per day. Prior to the focus group, the

[2]https://www.medicspot.co.uk

University of the West of England (UWE) Research Ethics Committee has given full ethical approval to conduct this focus group, reference number FET.21.04.048, and Banphaeo General Hospital has provided the approval letter to conduct the research with their medical staff.

The focus group were conducted virtually via Microsoft Teams since we run the study in United Kingdom while the participants work in Thailand. Going back to Thailand for an in-person focus group is not feasible due to the long distance between two countries and COVID-19 situation. To gather information more effectively and avoid misinterpretation, Miro[3], an online collaborative whiteboard platform, is employed in the focus group. It allows the participants to remotely collaborate with each other. They can add notes as much as they want which facilitates more effective data gathering and results analysis. In addition, the data in Miro board are permanent digital records, and notes can be clustered to aid in analysis.

The section took approximately three hours and started with the informal conversation to place the participants at ease and offer the participants an opportunity to ask further questions prior to gaining written consent. Then, the participants were given the link to access Qualtrics[4], an online survey tool, to fill the consent form, provide their demographic details and answer a few questions, including the frequency of giving general examination, the typical steps of general examination, and the tasks of each participant when giving general examination[5].

After that, the participants and the researcher discussed the specific topics one by one, where each question is assigned to a separate area of the Miro board to ensure that the participants will focus on a certain question at a time. Then, they were encouraged to add comments on Miro board and clarify by explaining in speech. During a focus group, a brief introduction of virtual reality (VR), desktop augmented reality (AR) display, and social robot was presented to the participants to be more familiar and understand the questions regarding to these topics properly. There are six main topics to be discussed on the Miro board as follow:[6].

1) List the most common ailments they found among patients and describe the information that they have to observe by filling the table and adding extra comments if needed.
2) Define the information they need in remote consultation to decide whether patients are required to come to a hospital to get an in-person care or not. They can use sticky notes to answer what they need for making a decision.
3) Provide opinions about strength and drawbacks on different types of remote consultation technologies (Questionnaires, Messages, Phone call, Video call, etc.).
4) Rate the remote consultation technologies in five different aspects (Learnability, Efficiency, Memorability, Errors, Satisfaction). Different colours of sticky notes represent different technologies.
5) Name the features for a robot teleoperation system, explain what they expect the robot to do, and prioritize the most important required features.
6) Choose the preferred interface between virtual reality (VR), and a desktop augmented reality (AR) display and state the reasons and provide opinions on using social robot.

[3]https://miro.com

[4]https://www.qualtrics.com

[5]The template of the questionnaires for medical staff can be assessed by clicking on this link

[6]The template of Miro board can be assessed by clicking on this link

B. Online survey with general people

After the focus group, a survey with general people is done via Qualtrics[7] to validate the result from patient's perspective. The survey contained 12 items asking about their demographic data, medical issues, attitude and expectation towards technology, and system design. In the survey, 42 people participated in the survey. The gender distribution amongst the people was 66.7% male and 33.3% female. Most of them suffered from fever, sore throat, headache, diarrhea, and runny nose 1-3 times per month.

After obtaining data from the focus group and the online survey, all data were sorted into sub-themes, summarized into main themes, and interpreted using a framework analysis [26]. The framework analysis has been widely applied in health research as it is a systematic and flexible to analyzing qualitative data [11]. Examples of using framework analysis can be found in [13], [35].

IV. USER REQUIREMENTS

As mentioned previously, the framework analysis is implemented to analyse the data gathered from the focus group and the online survey. There are roughly five main steps of framework analysis: Data Familiarisation, Framework Identification, Indexing, Charting, and Mapping and Interpretation.

In the first step of data familiarisation, a verbatim transcription is ideally needed. However, since the focus group was conducted in Thai with Thai medical staff, there is no platform available in Thai, and transcription has to be done manually. This is one of the reasons that Miro board has been implemented in the focus group so that the researcher does not need to transcribe the entire conversation in focus group. Then, the recording is re-listened to become more familiar with the interview. After that, framework identification is done by applying themes and sub-themes to essential information as many as possibles. In this study, the themes refer to, for example, necessary and optional features, preference tools, responsibility and ethical concerns. They are later compared and group into categories to form a working analytical framework. Our framework consists of four categories, namely *communication information*, *robot functionality*, and *safety and privacy*. Next, indexing is performed by applying existing working analytical framework to the data/transcripts. Note that this study does not use

[7]The template of the questionnaires for general people can be assessed by clicking on this link

any Computer Assisted Qualitative Data Analysis Software (CAQDAS) as there are currently no commercial CAQDAS available in Thai. Once the themes have been identified and indexed, the next step is to chart data into the framework matrix. To do so, the data is summarized into a matrix where each column represents a theme and each row represents the data/transcripts. Finally, by using the charting matrix, the user requirements for each category are identified and linked to three different user groups, i.e. doctors, patients, and assistants.

This section lists the derived requirements for three user groups (Section IV-A to Section IV-C). Additionally, we report more general requirements in Section IV-D. Note that the requirements are not given in any specific order.

A. Doctor's User Requirements

By analysing the data from the focus group, the user requirements for doctors are identified as follow:

- **D1** Doctors want to communicate with the patient in real-time. A chat system is also needed in case of poor connection.
- **D2** Doctors need the information of vital signs to be displayed on desktop augmented reality during the entire examination.
- **D3** Doctors want the assistant to navigate the robot to a safe place, monitor the robot and other equipment, introduce the patient to doctors and vice versa, and execute commands from doctors.
- **D4** To create a good first impression, doctors need robots to interact with the patient in a socially acceptable way.
- **D5** Doctors need a display on the robot to have the patient follow a certain examination or to log data.

B. Patient's User Requirements

According to the survey with general people, the requirements by the patients are clearly driven by the security and privacy concerns when using a teleoperation system. The user requirements for patients are identified as follows:

- **P1** Patients need the doctor to be present all the time, and therefore, real-time communication is necessary.
- **P2** Patients need the assistant to be nearby all the time.
- **P3** Patients need secure data connection to secure their privacy.

C. Assistant's User Requirements

Prior to the focus group, assistants were also invited to join the requirement analysis section. However, due to an emergency call, they were not able to participate in the focus group. Therefore, the user requirements for assistants are recommended by doctors which are identified as follows:

- **A1** Assistants need an interface to navigate the robot.
- **A2** Assistants need some features to transfer additional data to doctors, e.g. olfactory information

D. Other Requirements

- **O1** The system should provide an emergency button for assistants and patients to press in case of a technical failure. A remotely controlled emergency button should also be available for doctors.
- **O2** A self-check procedure should be run every time during initializing the system.

V. DISCUSSION

The user requirements for all three user groups for the robot teleoperation system are presented in this paper. In general, the findings from requirement analysis show that they are positive towards the idea of using robot teleoperation system for a general medical examination. In this section, we discuss how the derived requirements can be converted into system specifications, and describe the challenges and limitations found during the user studies.

According to the focus group and survey, it is crucial for the robot teleoperation system to support video conferencing between doctors and patients (**D1** and **P1**), while assistants should be nearby patients all the time (**P2**). As the main concerns for patients are the security and privacy aspects, they prefer doctors to have a conversation while keeping eye contact for the whole examination process. At the same time, they still need assistants to be nearby in case of technical failures and medical emergencies. In that case, emergency button must be provided for all users to stop the robot teleoperation system to prevent unexpected accident (**O1**). To ensure that the robot teleoperation system will operate properly, a self-check procedure will be run every time during initializing the system (**O2**).

During the examination, doctors need the information of vital signs to be displayed and desktop augmented reality (AR) was selected as an interface paradigm (**D2**). They mentioned in the focus group that virtual reality (VR) has a significant high learnability and memorability which may lead to more diagnostic errors compared to AR. Moreover, VR tends to induce motion sickness which is not practical for doctors to work for extended period. In addition, a VR head-mounted display must be worn to the head which may be inconvenient for doctors to have a quick access or leave the system in case of emergency call. To obtain the information of vital signs, several medical sensors will be carefully selected to achieve high accuracy while maintaining the cost. For instance, to measure temperature, it will be decided whether thermal camera or digital thermometer is a suitable tools depending on the accuracy and its practicability.

In order to instruct the patient, doctors need a display on the robot teleoperation system to have the patient to follow a certain examination (**D5**). This is one of the reasons that Pepper could be a possible teleoperation platform as it also provide a touch screen display on its chest. Therefore, patients can use the display on Pepper robot to log data or chat to doctors in case of unstable internet connection (**D1**). Despite the unstable network, the connection should still be secure for the transmission of the patient's medical information (**P3**). To implement a secure data connection, the researcher is going to corporate with UWE Data Protection Office who demonstrate compliance with UK General Data Protection Regulation (UK GDPR).

For the navigation system, doctors want the assistant to be mainly in charge (**D3**), and therefore, the interface for navigation should be provided for the assistant (**A1**). Although doctors specified in the focus group that navigation system is an optional feature for the robot teleoperation system, it is better to have the navigation interface for doctors as well. They will involve in the design phase to determine how the robot should be controlled.

Considering about the robot's social aspects, doctors need the robot to interact with the patient in a socially acceptable way so as to impress and increase social interaction (**D4**). Nevertheless, they did not mention any specific behaviour that they do or do not want the robot to express. Thus, to design socially-acceptable behaviour of the robot, we will need to consider the behaviour of the robot in different scenarios. One challenging example is that when doctors explain about patients' serious conditions, some patients may get encouraged if the robot expresses happy mood. Others may feel that the robot is mocking at them, Another example is that as Thailand is a high-context culture country, it is important to consider what extent should the robot behave in a cultural way. Lastly, if the video conferencing communication between doctors and patients is disabled due to poor network, what kind of behaviour should the robot express during the absence of doctors in order to keep social interaction with patients in a socially-acceptable way.

Lastly, in the focus group, apart from the current user requirements, doctors mentioned several optional features that could implement on the robot, for example, digital stethoscope for auscultation and headphone for measuring audiometry. It is also found that two of four doctors are often not fully aware of the limitations of current robotic systems. There are several features that they would like the robot teleoperation system to achieve which may not be feasible. These could be, for example, having a microscopic view to view tissue pathology, otoscopic view to see outer-middle ear canal, ophthalmoscopic view to see eye ground, and nasoscopic view to see nasal cavity and throat. Some features are technically achievable but come with high implementation costs i.e. oxygen defibrillator, ultrasonography, blood gas interpretation, etc. Hence, they suggested that any information that cannot be examined via the robot teleoperation system e.g. olfactory information can have the assistant to transfer to them (**A2**).

In this requirement analysis, there are several challenges and limitations that we found during the focus group and online survey. In the focus group, it is difficult to recruit the participants from Banphaeo General Hospital because they have a very tight schedule to attend to the COVID-19 patients which the number tends to increase over time. Therefore, only young GPs who are in the age between 18 and 35 years and have more time were recruited. So, one limitation is the lower generality of the result since the user requirements might differ for the older GPs. Also, the doctor's user requirements is more specific to our use cases in general medical examination (e.g. (**D2**)). While desktop augmented reality is preferred in this case, virtual reality might be more suitable for other types of telemedicine system. Although the participants agreed to be recruited, arranging a date for a focus group turned out to be challenging. As every Thai medical staff is responsible for a night shift at a certain day, finding a day on which all participants were able to join was difficult. Interviewing them individually is not the viable solution as it does not allow participants to exchange viewpoints and discuss the requirements together. Prior to the focus group, there were five medical staff who agreed to participate in the study. However, at the date of focus group, one of them had an emergency night shift, and hence, cannot participate in the focus group. For the online survey, since the researcher runs the study in United Kingdom because of COVID-19 situation, the only feasible solution to distribute the survey was to publish via social media. Generally, only young Thai people use social media frequently, and this is the main reason why there are no others but the age group of 18 to 35 years participate in the survey. This could probably be avoided if there are more time to collect the data from the survey.

VI. CONCLUSIONS

In this study, we implemented a user-centred design process to develop a robot teleoperation system for general medical examination. We present a list of requirements for doctors, patients, and assistants, and discuss how the collected requirements can be transferred into technical specifications of the system. We found that the requirements fall into four categories, regardless of user group.

The highest priority among four categories is communication (**D1**, **P1**, **P2**) among different user groups. Doctors need to access the health status of their patients, and patients need doctors and assistants to be in charge of the robot teleoperation system.

The requirements considering about information (**D2**, **D3**, **A2**) fall into second category. Doctors need to know all medical information e.g. vital signs, in which the assistants should prepare and transfer to the doctors.

Robot functionality (**D4**, **D5**, **A1**) is a third set of requirements. For technical requirements, doctors need a display on the robot and assistants need interface for navigating the robot. For social aspects, doctors want the robot to express social interaction in an acceptable way.

Finally, safety and privacy (**P3**, **O1**, **O2**) are the last set of user requirements. Safety of the end users is very crucial, and therefore, the robot teleoperation system should be built and designed together with the end users. In addition, secure data transfer is necessary to guarantee the privacy of patients.

We argue that the list of user requirements will drive this development and testing in the future. After the requirement analysis, the required medical sensors and tools will be identified and integrated with the robot teleoperation system, and later, the medical staff will take part in the user interface design and system evaluation.

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REFERENCES

[1] P. Arbeille, A. Capri, J. Ayoub, V. Kieffer, M. Georgescu, and G. Poisson. Use of a robotic arm to perform remote abdominal telesonography. *AJR. American journal of roentgenology*, 188(4):317–322, 2007.

[2] J. Armstrong and W. S. Haston. Medical decision support for remote general practitioners using telemedicine. *Journal of Telemedicine and Telecare*, 3(1):27–34, 1997.

[3] K. Boman, M. Olofsson, P. Berggren, P. P. Sengupta, and J. Narula. Robot-assisted remote echocardiographic examination and teleconsultation: A randomized comparison of time to diagnosis with standard of care referral approach. *JACC: Cardiovascular Imaging*, 7(8):799–803, 2014.

[4] G. Brandt, A. Zimolong, L. Carrât, P. Merloz, H. W. Staudte, S. Lavallée, K. Radermacher, and G. Rau. CRIGOS: A compact robot for image-guided orthopedic surgery. *IEEE Transactions on Information Technology in Biomedicine*, 3(4):252–260, 1999.

[5] A. Buvik, E. Bugge, G. Knutsen, A. Småbrekke, and T. Wilsgaard. Patient reported outcomes with remote orthopaedic consultations by telemedicine: A randomised controlled trial. *Journal of Telemedicine and Telecare*, 25(8):451–459, 2019.

[6] Y. Cai, Y. J. Zheng, A. Gulati, A. Butrymowicz, R. Krauter, S. D. Pletcher, J. D. Sharon, A. N. Goldberg, and J. L. Chang. Patient Use of Low-cost Digital Videoscopes and Smartphones for Remote Ear and Oropharyngeal Examinations. *JAMA Otolaryngology - Head and Neck Surgery*, 147(4):336–342, 2021.

[7] K. Carranza, N. J. B. Day, L. M. S. Lin, A. R. Ponce, W. O. Reyes, A. C. Abad, and R. G. Baldovino. Development of a telepresence robot with integration of a general practice medical consultation module. *International Journal of Engineering and Technology(UAE)*, (566), 2018.

[8] K. A. R. Carranza, N. J. B. Day, L. M. S. Lin, A. R. Ponce, W. R. O. Reyes, A. C. Abad, and R. G. Baldovino. Akibot: A telepresence robot for medical teleconsultation. *2018 IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management, HNICEM 2018*, pages 5–8, 2019.

[9] H. Erel, D. Trayman, C. Levy, A. Manor, M. Mikulincer, and O. Zuckerman. Enhancing Emotional Support: The Effect of a Robotic Object on Human–Human Support Quality. *International Journal of Social Robotics*, 2021.

[10] F. Fatehi, M. Martin-Khan, A. C. Smith, A. W. Russell, and L. C. Gray. Patient Satisfaction with Video Teleconsultation in a Virtual Diabetes Outreach Clinic. *Diabetes Technology and Therapeutics*, 17(1):43–48, 2015.

[11] N. K. Gale, G. Heath, E. Cameron, S. Rashid, and S. Redwood. Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Medical Research Methodology*, 13(1):117, dec 2013.

[12] M. Giuliani, D. Szczęśniak-Stańczyk, N. Mirnig, G. Stollnberger, M. Szyszko, B. Stańczyk, and M. Tscheligi. User-centred design and evaluation of a tele-operated echocardiography robot. *Health and Technology*, 10(3):649–665, 2020.

[13] T. Gorst, A. Lyddon, J. Marsden, J. Paton, S. C. Morrison, M. Cramp, and J. Freeman. Foot and ankle impairments affect balance and mobility in stroke (FAiMiS): The views and experiences of people with stroke. *Disability and Rehabilitation*, 38(6):589–596, 2016.

[14] M. Hadziahmetovic, P. Nicholas, S. Jindal, P. S. Mettu, and S. W. Cousins. Evaluation of a Remote Diagnosis Imaging Model vs Dilated Eye Examination in Referable Macular Degeneration. *JAMA Ophthalmology*, 137(7):802–808, 2019.

[15] R. Handschu, R. Littmann, U. Reulbach, C. Gaul, J. G. Heckmann, B. Neundörfer, and M. Scibor. Telemedicine in Emergency Evaluation of Acute Stroke: Interrater Agreement in Remote Video Examination with a Novel Multimedia System. *Stroke*, 34(12):2842–2846, 2003.

[16] M. Hann and H. Gravelle. The maldistribution of general practitioners in England and Wales: 1974-2003. *British Journal of General Practice*, 54(509):894–898, 2004.

[17] C. Kanchanachitra, M. Lindelow, T. Johnston, P. Hanvoravongchai, F. M. Lorenzo, N. L. Huong, S. A. Wilopo, and J. F. Dela Rosa. Human resources for health in southeast Asia: Shortages, distributional challenges, and international trade in health services. *The Lancet*, 377(9767):769–781, 2011.

[18] J. Kitzinger. Qualitative Research: Introducing focus groups. *BMJ*, 311(7000):299–302, jul 1995.

[19] G. Labiris, M. Fanariotis, C. Christoulakis, A. Petounis, G. Kitsos, M. Aspiotis, and K. Psillas. Tele-ophthalmology and conventional ophthalmology using a mobile medical unit in remote Greece. *Journal of Telemedicine and Telecare*, 9(5):296–299, 2003.

[20] A. M. R. Nielsen. Co-constructing the Video Consultation-competent patient. *Social Interaction. Video-Based Studies of Human Sociality*, 3(3), 2020.

[21] H. Nishiura, S. Barua, S. Lawpoolsri, C. Kittitrakul, M. M. Leman, M. S. Maha, and S. Muangnoicharoen. Health inequalities in Thailand: Geographic distribution of medical supplies in the provinces. *Southeast Asian Journal of Tropical Medicine and Public Health*, 35(3):735–740, 2004.

[22] D. A. Norman and S. W. Draper. *User Centered System Design: New Perspectives on Human-Computer Interaction*. L. Erlbaum Associates Inc., USA, 1988.

[23] Y. Onishi, K. Tanaka, and H. Nakanishi. Embodiment of video-mediated communication enhances social telepresence. *HAI 2016 - Proceedings of the 4th International Conference on Human Agent Interaction*, pages 171–178, 2016.

[24] A. Padarath, C. Chamberlain, D. McCoy, A. Ntuli, M. Rowson, and R. Loewenson. Health personnel in Southern Africa: confronting maldistribution and brain drain. *Equinet Discussion Papers*, 4(1):1–41, 2003.

[25] C. Preusche, T. Ortmaier, and G. Hirzinger. Teleoperation concepts in minimal invasive surgery. *Control Engineering Practice*, 10(11):1245–1250, 2002.

[26] J. Ritchie and L. Spencer. Qualitative data analysis for applied policy research. In *Analyzing qualitative data*, pages 187–208. Routledge, 2002.

[27] B. Robins, K. Dautenhahn, R. T. Boekhorst, and A. Billard. Robotic assistants in therapy and education of children with autism: Can a small humanoid robot help encourage social interaction skills? *Universal Access in the Information Society*, 4(2):105–120, 2005.

[28] H. A. Rothan and S. N. Byrareddy. The epidemiology and pathogenesis of coronavirus disease (COVID-19) outbreak. *Journal of Autoimmunity*, 109(February):102433, 2020.

[29] B. Salafsky, M. Glasser, and J. Ha. Addressing issues of maldistribution of health care workers. *Annals of the Academy of Medicine Singapore*, 34(8):520–525, 2005.

[30] G. Stollnberger, M. Giuliani, N. Mirnig, M. Tscheligi, K. Arent, B. Kreczmer, F. Grzeszczak, D. Szczesniak-Stanczyk, R. Zarczuk, and A. Wysokinski. Designing user interfaces for different user groups: A three-way teleconference system for doctors, patients and assistants using a Remote Medical robot. *25th IEEE International Symposium on Robot and Human Interactive Communication, RO-MAN 2016*, pages 612–617, 2016.

[31] G. Stollnberger, C. Moser, E. Beck, C. Zenz, M. Tscheligi, D. Szczesniak-Stanczyk, M. Janowski, W. Brzozowski, R. Blaszczyk, M. Mazur, and A. Wysokinski. Robotic systems in health care. In *2014 7th International Conference on Human System Interactions (HSI)*, pages 276–281. IEEE, jun 2014.

[32] G. T. Sung and I. S. Gill. Robotic laparoscopic surgery: A comparison of the da Vinci and Zeus systems. *Urology*, 58(6):893–898, 2001.

[33] R. Tanioka, R. Locsin, Y. Yasuhara, and T. Tanioka. Potential Legal Issues and Care Implications during Care-Prevention Gymnastic Exercises for the Elderly Using Pepper in Long Term Health Care Facilities. *Intelligent Control and Automation*, 09(03):85–93, 2018.

[34] A. Tapus, C. Tapus, and M. Mataric. The role of physical embodiment of a therapist robot for individuals with cognitive impairments. In *RO-MAN 2009 - The 18th IEEE International Symposium on Robot and Human Interactive Communication*, pages 103–107. IEEE, sep 2009.

[35] A. J. Turton, J. Angilley, M. Chapman, A. Daniel, V. Longley, P. Clatworthy, and I. D. Gilchrist. Visual search training in occupational therapy - An example of expert practice in community-based stroke rehabilitation. *British Journal of Occupational Therapy*, 78(11):674–687, 2015.

[36] Y. Zhou, P. Robot, and H. Assistant. *Robot Application In The Medical Area*. PhD thesis, Vaasa University of Applied Sciences, 2019.