別紙４－２（課程博士（和文））

２０２０　年　９　月　２５　日

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論文内容の要旨　（博士）

博士学位論文名	医療介護施設での移乗および回診支援のための移動ロボットの設計と制御

（要旨　1,200 字程度）

　産業分野で培われたロボット技術は，近年，医療・福祉分野を含む様々な分野へ応用展開されている．現在，日本では少子高齢化に伴う労働者の慢性的不足や高齢者が高齢者を介護する「老老介護」が大きな問題になっている．これらの解決策として被介護者の自立的な生活の支援や介護者の身体的負担の軽減を目的とした医療福祉分野のロボット開発が期待され，行政の支援も活発に行われている．

　本研究では，超スマート社会の実現（Society 5.0）におけるスマートな健康支援社会を構築するためのコア技術である医療福祉介護ロボットにおいて，特に介護分野で重要である二つの主要テーマを取り扱う．一つは介護で最大の問題となっている移乗である．もう一つは，医療従事者の業務サービス支援である医療介護施設内回診や上記移乗等に伴う移動ロボットの人物追尾である．

　一つ目の主要テーマでは「全方向に即時に移動可能なパワーアシスト式移乗介護ロボット」の開発を目標としている．このロボットでは，移乗のためのリフト機構に加え，全方向移動を可能とする差動駆動操舵機構（Differential Drive Steering System: DDSS）を用いている．力覚センサによるロボットの移動操作量推定およびリフト機構のワイヤ傾斜量を用いた牽引物への操作力推定に基づくパワーアシスト技術によって，直感的な操作感を実現している．さらに，リフト機構においては，牽引物の荷重を計測することで上下移動のための操作力を推定し，アシストする機能を有している．この上下移動のアシストにおいては，従来の研究においてリミットサイクルの発生が報告されているが，牽引物に荷重計測に基づき，これを回避する制御手法を提案している．以上の機能を融合して開発されたロボットは，移乗のみならず，移乗後に車椅子としての移動が可能な統合型システムとして設計されている．

　また，リフト装置の実用化において高価なセンサの利用は現実的でないため，安価なセンサに用いて吊り上げ作業時に発生する揺れを低減できる制御手法を提案している．吊り上げ作業中に発生するワイヤの特徴的な張力変化を検出し，巻上速度を動的に制御することで，地切り時に発生する揺れを低減し，実験的に有用性を確認している．

　二つ目の主要テーマとして，回診・移動ロボットの人物追尾システムの研究を行っている．上記の移乗を含め病院などで用いられる移動ロボットでは，医療従事者などへの人物追尾システムの利用が期待されている．同システムにおける追尾対象者の見失いを回避するために，追尾対象者に加速度センサを取り付け，既存のレーザーセンサとのセンサーフュージョンにより，追尾対象者の移動量を推定する手法を提案し，制御実験により有用性を確認している．

　これらの研究成果により，医療・介護現場における医療福祉ロボット技術開発における学術的および実用化への基礎的知見を得ている．

別紙４－１（課程博士（英文））

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Abstract（Doctor）

Title of Thesis	Design and Control of a Mobile Robot to Support Transfers and Rounds in Medical Care Facilities

Approx. 800 words

In recent years, the robot technology cultivated in the industrial field has been applied to various fields including the medical and welfare fields. Currently, in Japan, the chronic shortage of workers due to the declining birthrate and aging and the "elderly care" in which the elderly take care of the elderly are becoming major problems. As a solution to these problems, the development of robots in the medical and welfare field with the aim of supporting the care recipient's independent life and reducing the physical burden on the caregiver is expected, and administrative support is being actively provided.

For this reason, various nursing care devices using robot technology are currently being researched and developed. However, in actual sites, although lift devices, power assist suits, transfer assistance robots, and so on have been researched and developed for transfer assistance work that is physically demanding, it cannot be said that these are effectively utilized. Since the lift device is generally moved manually, the reduction of the workload is limited. Furthermore, the swaying that occurs when transferring causes discomfort to the cared person, and also presents a dangerous situation where safety and security are lacking. As part of the development of smart hospital, our group is conducting research on a roundabout and transfer robot that can support human medical personnel, but it is necessary to solve the occlusion problem that causes oversight in the invisible region.

This study deals with two major themes that are particularly important in the field of care in medical and welfare care robots, which are the core technology for building a smart health support society in the realization of a super smart society (Society 5.0). One is transfer/movement, which is the biggest problem in nursing care. The other is a roundabout/movement within a medical/nursing facility, which supports the business services of medical staff at medical facilities. In this research, we conducted robot research to support humans in these two tasks.

By using a differential drive steering system (DDSS) as the omnidirectional movement mechanism, for the first major theme, movement without any limitation in the movement direction is realized. The power assist technology

using a force sensor for the moving operation gives an intuitive operation feeling in any direction. For the lift mechanism, we propose a power assist mechanism that measures the load of the towed object, detects the vertical movement amount by the operating force applied to it, and detects the horizontal movement amount from the wire inclination amount, and enables the lift movement. In addition, we proposed a new power assist control method that avoids the limit cycle generated in the previous research. The developed robot is an integrated system that can be used not only for transfer, but also as a transfer device for wheelchairs immediately after transfer.

Next, a safe and secure control method that reduces swing generated during lifting work by an inexpensive and simple control method without using an expensive sensor that is considered difficult to use in a commercially available lift device. The hoisting speed is dynamically controlled by the load change generated on the wire during hoisting work to reduce the sway generated during ground cutting and confirm its usefulness.

Now, as the second major theme, we have conducted research on rounds and mobile robots. By the way, a person tracking system is often used in transport robots and roundabout robots including the above movable care lift in hospitals and etc. As a method of avoiding the tracking target person's loss of sight in tracking control of a care support transport robot, we propose a method to estimate the movement amount of the tracking target person by attaching an acceleration sensor to the tracking target person and using sensor fusion with the existing laser sensor. The effectiveness is verified by control experiments.

By these research results, we aim to obtain basic knowledge for academic and practical application in medical and welfare robot technology development in medical and nursing care settings.