様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科学研究費助成事業　　研究成果報告書

令和　　元 年　　６ 月 １８ 日現在

機関番号：１１６０１
研究種目：若手研究(B)
研究期間：2017～2018
課題番号：１７Ｋ１２７５７

研究課題名（和文）Dynamic braking of omni-wheel rollers for dual robot cooperative task execution

研究課題名（英文）Dynamic braking of omni-wheel rollers for dual robot cooperative task execution

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交付決定額（研究期間全体）：（直接経費）　　3,200,000円

研究成果の概要（和文）：当初の目的は可変ブレーキ力を各オムニホイールローラに加えることができる機構だったが、各ローラに均一な力をかけることが困難であることが分かった。ここで、マグネットギアを利用した伝達機構を考案した。このギアは非接触で複数のギアを同時に駆動ができる。市販の小型マグネットギアと試作した形の大きいマグネットギアを利用してローラに力伝達できるオムニホイールを開発した。開発したオムニホイールを２台の対向二輪型ロボットに適用し制御を開発した。可変ブレーキを利用し新しい動作が実現できシステムの移動能力が向上できたとみられた。開発した車輪について学術講演で発表したら2件のベストプレゼンテーション賞を受賞した。

研究成果の学術的意義や社会的意義
To the best of the author's knowledge, roller braking is a new technique that has not yet been explored by other researchers. The developed magnetic transmission based omni-wheel is unique and can be used as a platform of new development for wheeled mobile robots.

研究成果の概要（英文）：The original proposal aimed to develop an omni-wheel with the capability of applying dynamic braking on the wheels. However, this proved difficult due to the imbalances in the applied braking force between different rollers. And so the author focused on the development of a transmission system able to apply torque to all rollers from one device. The developed magnet gear system has a central magnet gear connected to the braking device and small magnet gears embedded in the rollers. As a result, the mechanism is not only able to apply a braking force but an actuating force as well which exceeds the initial proposal. A cooperative differential drive test robot platform equipped with the developed wheels was implemented and tests showed that dynamic braking improves mobility as predicted. The author received two Best Presentation awards from two conferences the JSME Robomech 2018 and the SICE System Integration 2018.

研究分野：Mobile Robots

キーワード：Omni-wheel　Dynamic Braking　Magnet wheel　Actuated roller　Transmission System

１．研究開始当初の背景

The research focuses on the improvement of the mobility of the Inverted PENdulum Assistant Robot (I-PENTAR) during cooperative tasks. The cooperative behavior will extend the ability of the I-PENTAR of effectively using its balance for lifting objects to transporting larger objects. However, the design of typical mobile robots suffers from kinematic constraints that minimize the mobility of the cooperative system especially in tight indoor spaces.

The solution developed by the author is an omni-wheel with dynamic braking of the rollers. This was implemented using a new and novel mechanism developed by the author and is based on magnet gears. The development of this mechanism opens new effective tasks for the I-PENTAR and is considered by the author to be a contribution to the field of wheeled mobile robots.

２．研究の目的

The research aims to improve the mobility of the I-PENTAR during cooperative tasks especially in the dual robot case. Specifically, the research focuses on developing a mechanism for dynamic braking of omni-wheel rollers; modeling of the equations of motion of the cooperative I-PENTAR system; and implementing control techniques that utilize dynamic braking of the rollers. In doing so, it will explore a new area of cooperative robot behavior for the I-PENTAR and other wheeled mobile robots.

３．研究の方法

The improvement of the maneuverability of the I-PENTAR for cooperative tasks will begin with the development of the dynamic braking mechanism. A scaled up prototype of a single roller with a dynamic braking mechanism will be developed. This will be used to test and evaluate several methods for dynamic braking. Once the braking method is determined the prototype will be scaled down and a prototype omni-wheel with dynamic braking will be developed and evaluated. Then the wheel design is finalized and two robots utilizing the wheels will be built. Finally, the control of the cooperative system will be developed and evaluated.

４．研究成果

The original proposal aimed at developing an omni-wheel with the capability of applying dynamic braking on the wheels. However, during experimentation with the proposed shorted coil and magnet design, shown in Fig.1, several challenges were met.
First, with the scaled up version the size of the coil and the corresponding magnet would have to be significant to incur a noticeable braking force. This means that the scaled down version would have an even lesser equivalent braking force. Secondly, the air gap between the magnet and the coil would have to be very small to generate a significant braking force which would make designing the variable airgap mechanism for all rollers attached to the wheel difficult. Also, it was noticed that the braking force is very sensitive to the change in the airgap making the design impractical for an actual wheel. It was decided that a different mechanism be designed for the wheel.

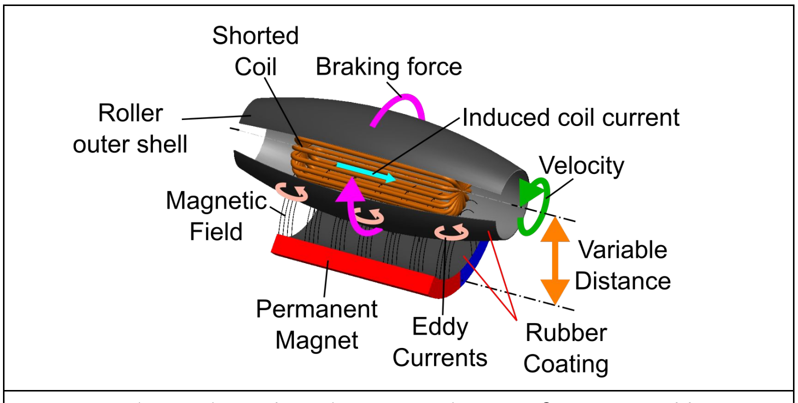

Fig.1 Shorted coil and magnet design for one roller

The author focused on a different implementation based on the idea of developing a transmission system for an omni-wheel that would allow the braking force to be applied to all the rollers from one device. This allows a more uniform force to be applied to the different rollers and would allow the use of off-the-shelf braking devices. The initial design was based on a magnet gear system that allows a single central magnet gear to transfer torque to several magnet wheels. This mechanism was used to implement the omni-wheel shown in Fig.2. The design uses small magnet wheels embedded into the rollers while a larger magnet wheel was developed by the author using permanent magnets embedded into a wheel cast.

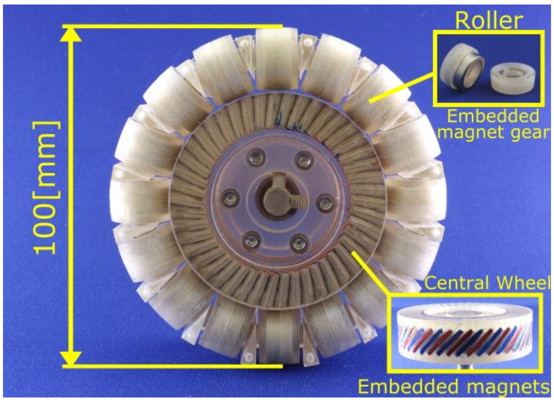

Fig.2 Multi-roller magnet wheel based transmission

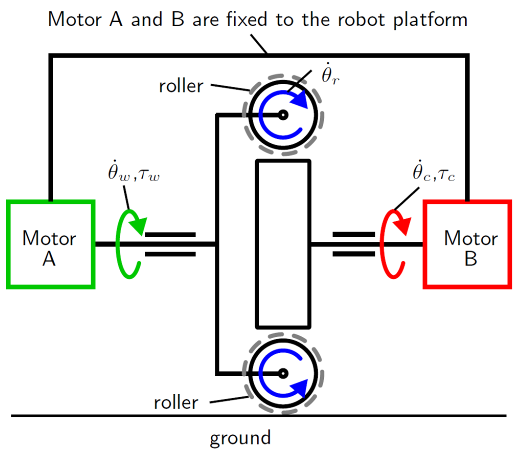

Fig.3 Simplified schematic of wheel with differential velocity based braking

Using the magnet wheel based omni-wheel system a braking method using differential velocity braking was developed. The functionality can be easily understood by looking at Fig.3 where the rotation of the entire wheel is actuated by Motor A and Motor B actuates the central magnet wheel. Note that the roller velocity is determined by the difference in the velocity between the velocities of Motor A and B. By designing a control that lets Motor B follow the velocity of the Motor A proportional to some gain K, braking can be achieved.

Using differential velocity based braking, a dual differential drive robot system was prototyped (Fig.4) that used the developed wheels. The model of the system was developed and analysis showed that the maneuverability of differential drive systems can be improved using dynamic braking.

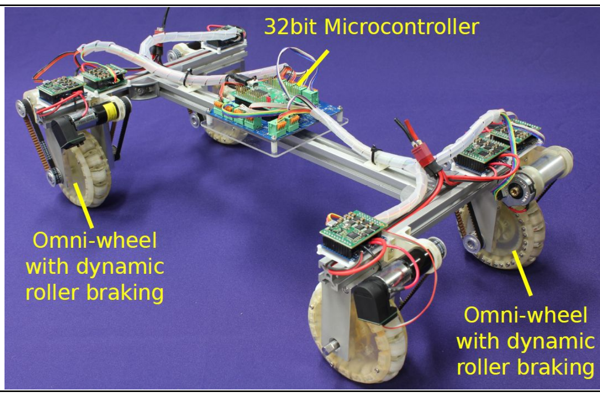

Fig.4 Prototype of dual differential drive robot system with dynamic roller braking wheels

Other advantages were also determined during the development of the wheel. For one, if there is available torque, the system can be used to actuate the wheels directly to create enable complete omnidirectionality. Another advantage is that since the rollers transmit motion to the central wheel an encoder can be attached to the central wheel that allows roller velocity feedback using one device. This feature cannot be achieved by ordinary omni-wheels and is a special feature to the developed omni-wheel.

５．主な発表論文等

〔学会発表〕（計　４件）

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