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Glazed Panel Construction with Human–Robot Cooperation

Springer

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Preface

Recently, the tendency for buildings and structures is to be ever larger and taller. A new method of construction is, therefore, required to follow the current trend, and construction machinery and equipment are being developed to help in the process at various construction sites. An imbalance in technical manpower supply and demand is a serious problem on construction sites. This labor shortage and the aging of the skilled worker on the construction site cause a lasting increase in wages. These technical service problems have appeared to lower functionality in construction situations. Consequently, the rising labor costs, poorer execution quality, delayed construction period, and increased construction expenses have led to reduced safety and more accidents in construction areas. This problem corresponds to the potential for "automation system and robotics in construction" as one of the solutions. It is possible to substitute an automatic system and robot for technical manpower, which simultaneously increases the working speed and construction quality, improves safety and reduces the cost of construction.

Generally, almost half of construction work is said to be material handling. Materials and equipment used for construction are heavy and bulky for humans. Through the case studies on constructions, to which building material handling robot was applied, however, we could find some factors to be improved. Unlike the automation lines of the general manufacturing industry, construction sites rarely shows repeated operational patterns use to its unstructured processes. That is, construction robots execute orders while operating in a dynamic environment where structures, operators, and equipment are constantly changing. Therefore, a guidance or remote–controlled system is the natural way to implement construction robot manipulators. However, a remote–controlled system has to solve some problems. One of the solutions to address these problems is the technology of human–robot cooperative manipulation.

The purpose of this study is to develop human–robot cooperative manipulation technology to solve all kinds of problems generated by the current installation method, which depends on manpower or a low-quality construction robot for the installation of heavy and bulk building materials at construction sites. The essential technologies of human–robot cooperative manipulation are considered through the analysis of an existing installation method. The prototype's hardware design and control algorithm development are achieved using the results of this analysis. The developed prototype system is corrected and complemented based on the results of a performance test. To apply human–robot cooperative manipulation at real construction sites, we executed additional work required for application. After application to real construction sites, evaluation on the productivity and safety of the developed system was done by comparing and analyzing with the existing installation methods. Lastly, I would like to acknowledge that this book would not exist without the support of my spouse, SAMSUNG CORPORATION.

Notations

Symbol	Description
$\underline{\mathbf{F}}_{\mathbf{h}}(\underline{\mathbf{T}}_{\mathbf{h}})$	The force (torque), measured by the operational force sensor which is generated by the interaction between the operator and HRI device
$\underline{\mathbf{F}}_{\mathbf{e}}(\underline{\mathbf{T}}_{\mathbf{e}})$	The force (torque), measured by the environmental force sensor which is generated by the interaction between the environment and a heavy material
$\mathbf{M}_{\mathbf{pt}}(\mathbf{M}_{\mathbf{ot}})$, $\mathbf{B}_{\mathbf{pt}}(\mathbf{B}_{\mathbf{ot}})$	The impedance parameters, that are related to a desired dynamic behavior, are $M_{pt}(M_{ot})$ and $B_{pt}(B_{ot})$, (n by n positive definite diagonal inertia and damping matrices), 'p' stands for the position and 'o' stands for the orientation
λ	The force augmentation ratio of an operator
$\mathbf{M}_{\mathbf{pe}}(\mathbf{M}_{\mathbf{oe}})$, $\mathbf{B}_{\mathbf{pe}}(\mathbf{B}_{\mathbf{oe}})$, $\mathbf{K}_{\mathbf{pe}}(\mathbf{K}_{\mathbf{oe}})$	The impedance parameters that determine a dynamic behavior of the end effector for interactions with an environment
$\{D\}$	The desired frame specified by a desired position vector $\underline{\mathbf{p}}_{\mathbf{d}}$ and a desired rotation matrix $\mathbf{R}_{\mathbf{d}}$
$\{C\}$	The compliant frame specified by a position vector $\underline{\mathbf{p}}_{\mathbf{c}}$ and a rotation matrix $\mathbf{R}_{\mathbf{c}}$
$\underline{\mathbf{p}}_{\mathbf{e}}$, $\mathbf{R}_{\mathbf{e}}$	The actual end effector position and orientation
$\dot{\underline{\mathbf{p}}}_{e}, \omega_e$	The actual end-effector linear velocity and angular velocity
$\mathbf{B}_{\mathbf{h}}$	The damping coefficient of an operator's arm
$\mathbf{K}_{\mathbf{h}}$	The stiffness coefficient of an operator's arm
$\ddot{\underline{\mathbf{X}}}_{d}$	Desired acceleration related target dynamics
$\dot{\underline{\mathbf{X}}}_{d}$	Desired velocity related target dynamics

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