

## Lowering Objects with a Power Assist Robot: the Preliminary Study

S. M. Mizanoor Rahman<sup>1, a</sup>, Ryojun Ikeura<sup>2, b</sup>, Soichiro Hayakawa<sup>2</sup>,  
Haoyong Yu<sup>1</sup>

<sup>1</sup>Division of Bioengineering, Faculty of Engineering, National University of Singapore

<sup>2</sup>Division of Mechanical Engineering, Graduate School of Engineering, Mie University, Tsu, Japan

<sup>a</sup>mizansm@hotmail.com; <sup>b</sup>ikeura@ss.mach.mie-u.ac.jp

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**Abstract.** We developed a 1-DOF power assist robot to lower objects from higher position to lower position. Subjects lowered objects of different sizes with the robot and we analyzed heaviness perception, load force, motions (displacement, velocity, acceleration) etc. We determined a psychophysical relationship between actual heaviness and perceived heaviness for objects lowered with the robot system. We tried to identify some control parameters from the analytical results, and proposed them to be used to determine and develop an appropriate control scheme for power assist robots for lowering heavy objects in various industries. This paper reports the preliminary study results on this issue.

### Introduction

Power assist robots are used mainly for rehabilitation and health supports [1], [2]. We tried to bring a novelty in power-assist applications in [3]. In [3], we argued that power assist devices could be used to handle heavy objects in various industries. However, the model presented in [3] deals with lifting objects in vertical direction only.

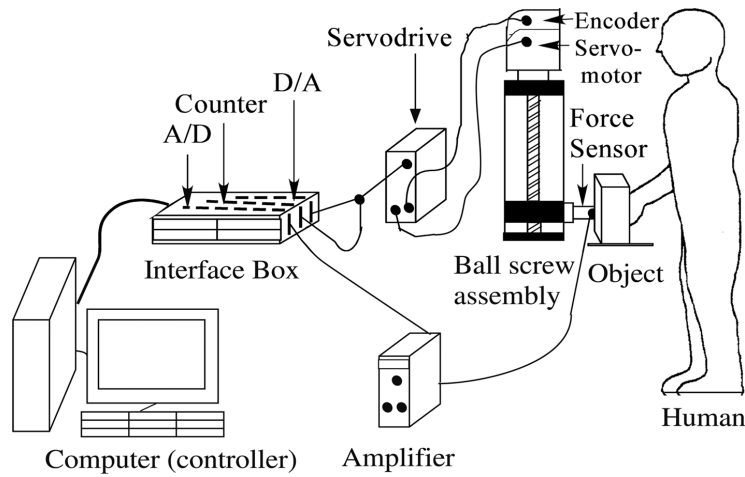
Workers in industries frequently lower heavy objects e.g. (i) when unloading heavy objects (luggage, bags etc.) from aircrafts, ships, buses, trains, trucks etc., (ii) when lowering heavy objects, materials, bags etc. in industries such as automobile, military services, agriculture, ship building and breaking, disaster and rescue operations, mining, manufacturing and assembly, construction, timber, forestry, daily household activities etc. However, lowering heavy objects manually is very hard, may cause disabilities and disorders in workers such as back pain, injuries, musculoskeletal problems etc., and on the contrary, uses of autonomous systems for lowering heavy objects may not provide flexibility and satisfactory interactions with humans.

We, therefore, assumed that human-robot systems such as power assist systems might be suitable and be comfortably used to lower heavy objects/materials in the aforementioned cases. However, suitable power assist devices for lowering heavy objects in industries are not so visible. Few models of power assist robots for objects manipulation are available [4], [5]. However, these models are not designed exclusively for lowering objects and almost all of them do not include human features such as human's heaviness perception in their controls and thus these models are not so human-friendly.

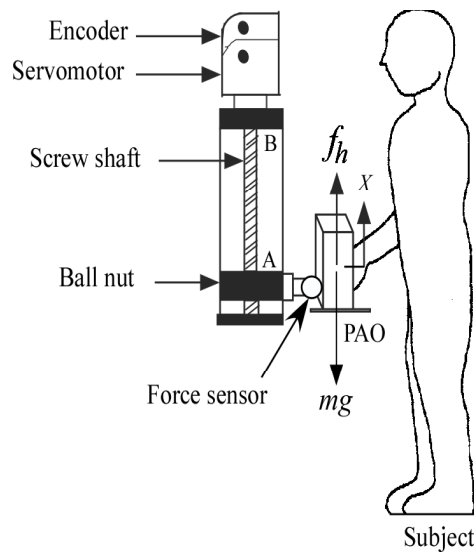
We took an initiative to develop a power assist robot for lowering heavy objects. Our strategy was to investigate human characteristics for objects lowering manually and then to compare the characteristics for lowering objects with power-assist and then to determine the appropriate control scheme for developing power assist robots for lowering heavy objects in industries. We studied human characteristics for lowering objects manually in [6]. In this paper, we would like to preliminarily study human characteristics (heaviness perception, load force, motions) for lowering objects with power-assist. Then, we will compare the characteristics between power-assisted and manual lowering of objects, and determine the control scheme for the proposed power assist robot.

## Materials

We developed a 1-DOF power assist robot system for lowering objects as shown in Fig.1. A ball screw assembly was actuated by a servomotor. A force sensor was tied to the ball nut of the ball screw. The object (rectangular thin aluminum box) was tied to the force sensor.



(a)



(b)

Fig.1 (a) 1-DOF power assist system for lifting/lowering objects. (b) Dynamics for lifting/lowering an object with the system.

We adopted a hypothesis pertaining to weight perception that perception of weight due to inertia differs from perceived weight due to gravity when manipulating an object with a power assist robot. For this reason, we thought that the mass parameter for inertia force might be different from that for gravity force for the dynamics of manipulating an object with the power assist robot [3].

## Methods

We simulated the system shown in Fig.1(a) using Matlab/Simulink (solver: ode4, Runge-Kutta; type: fixed-step; fundamental sample time: 0.001s). The mass parameter for inertia force ( $m_1$ ) was 0.5kg, and the mass parameter for gravity force ( $m_2$ ) was also 0.5kg because this condition has been proven as the high maneuverability condition in [3]. In each trial, the subject lowered an object from B to A (see Fig.1(b)) and we recorded heaviness perception, load force and motion features. The

subject compared the heaviness of the object lowered with the system to that of some reference weights and thus estimated the magnitude of the perceived heaviness of the power-assisted object in each trial. Few subjects independently lowered objects of three different sizes (large, medium, small) with the system.

## Results

The results showed that the perceived heaviness for power-assist-lowered objects were about 20% of the actual heaviness ( $m_2=0.5\text{kg}$ ) [7]. It means that the power-assist reduced the heaviness of the manipulated objects.

Displacement, velocity, acceleration and load force time trajectories for a typical trial for lowering the small size object with the power assist system are shown in Fig.2(a) and Fig.2(b). We determined mean peak velocity, peak acceleration and load force rate for lowering objects with the power assist

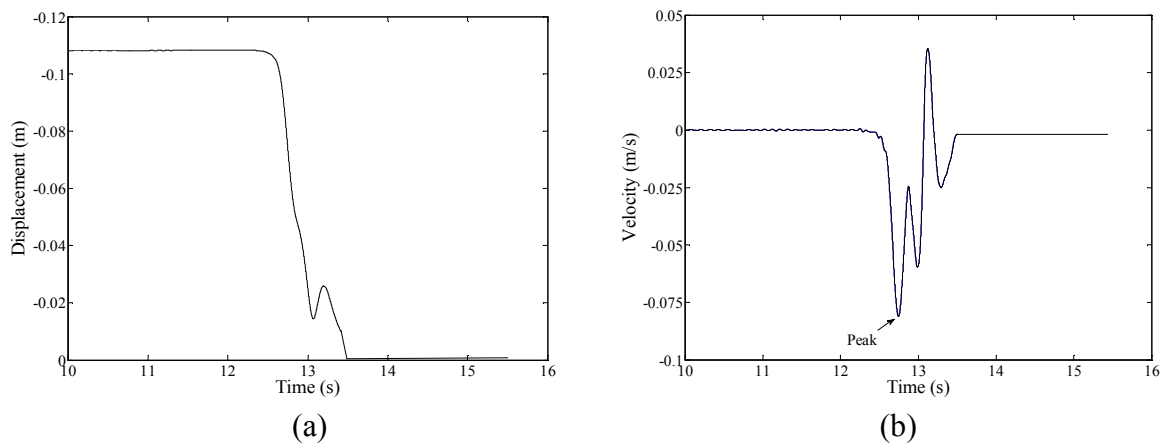
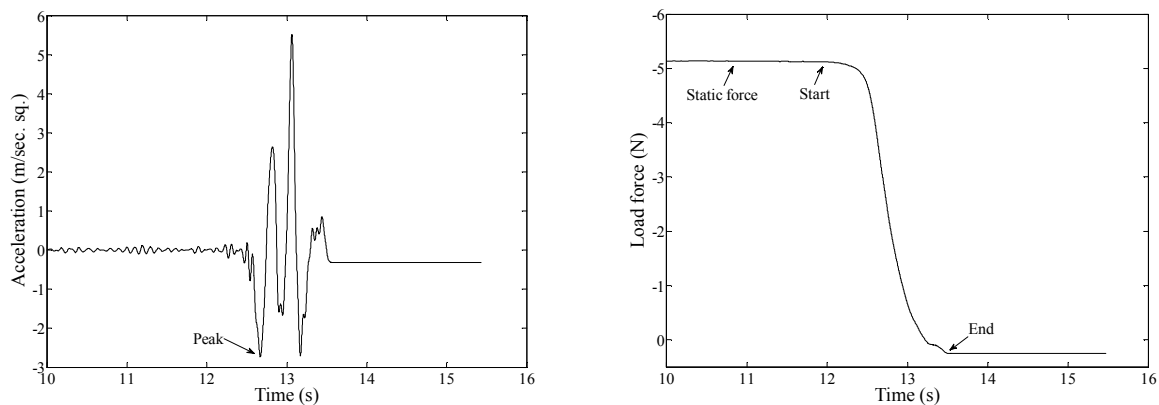


Fig.2 (a) Displacement, velocity, and (b) acceleration and load force time trajectories for a typical trial for lowering the small size object with the power assist system.

system and compared them to that for lowering objects manually [6]. The results showed that the peak velocity, peak acceleration and load force rate for lowering objects with the power assist system were much lower than that for lowering objects manually [7]. However, the peak velocity, peak acceleration and load force for lowering objects with the power assist system were much more excessive than the actual requirements [3],[7]. We assume that a suitable control method should be developed that provides appropriate perceived heaviness as well as results in appropriate motions when lowering objects with the system.



## Conclusions and Future Works

We developed a 1-DOF power assist system for lowering objects. We analyzed perceived heaviness, load force and motion features for lowering objects with the system and compared the findings to that for lowering objects manually. The results showed that the peak velocity, peak acceleration and load force rate for lowering objects with the power assist system were lower than that for lowering objects manually, and these were much more excessive than the actual requirements. The power assist system also reduced the perceived heaviness to 20%. The results will help develop appropriate control methods and strategies for power assist robots for lowering heavy objects in industries that we will address in near future.

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