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Towards Gyroscopic Balance Assistance: Proof of Concept*

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***Abstract*— In this paper, the feasibility of a Control Moment Gyroscope (CMG) as balance assistance device is investigated. An inverted pendulum is used as experimental set-up. Our initial results show that it is possible to maintain balance within a 4 degrees range from vertical.**

I. INTRODUCTION

Reducing falls is an urgent challenge in ageing societies, as falls are among the most frequent causes of hospitalization and death among the elderly [1]. A key factor leading to falls is degraded balance control. We proposed a minimalistic solution for balance assistance [2], which is based on a gyroscope assembly coupled to the upper body. By exploiting the effect of several control moment gyroscopes (CMGs), the required support is generated in the case of loss of balance. Here, we study technical feasibility of this approach using a single CMG mounted on an inverted pendulum (IP).

II. METHODS

The preliminary setup consists of a 5 kg CMG mounted on top of a 3 kg IP (Fig. 1). The CMG's flywheel spins at 3500 rpm about the $\hat{\boldsymbol{g}}_s$ axis. In order to avoid singularities (i.e. $\hat{\boldsymbol{g}}_t \parallel \hat{e}_u$) the CMG is initially positioned in such a way that $\hat{\boldsymbol{g}}_s \parallel \hat{e}_u$ (i.e. $\gamma = 0°$). In addition, γ is restricted within a $\pm 27.5°$ range. A spring-like behaviour (i.e. $\tau_{IP} = -k\phi$ with stiffness k, provided by the CMG about $\hat{e}_v$), similar to the ankle strategy while maintaining balance in quiet stance was implemented. Tests were performed with the IP starting at an inclination angle $\phi = 0°$, and by manually applying small perturbations at the top.

III. EXPERIMENTAL RESULTS AND DISCUSSION

When the perturbations were applied, the CMG provided enough support to keep the IP upright (within a $\phi = \pm 2°$ range). Moreover, the CMG tracked the desired torque on the IP well, with an RMS error of 0.55 Nm (Fig. 2). We presume that higher flywheel speeds (only a third of the flywheel angular velocity reported in [2] was used) will lead to higher moments, as needed for experiments with human subjects.

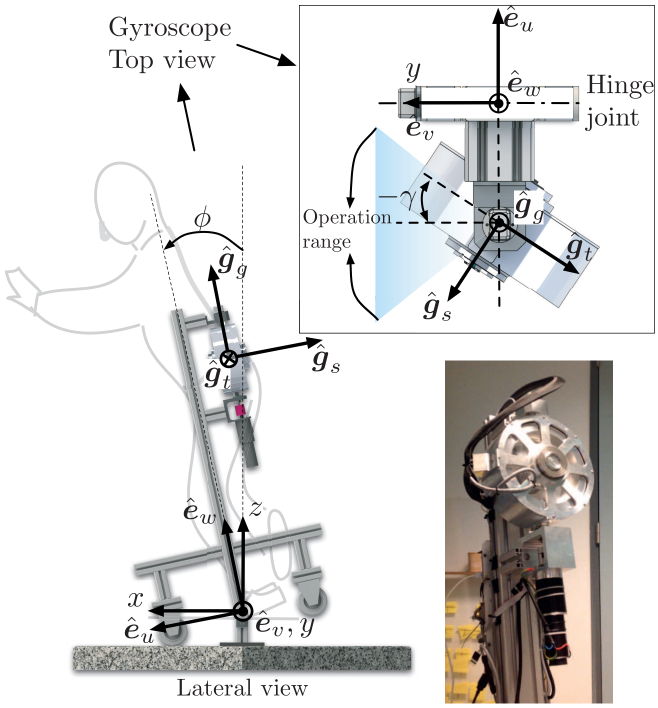

Fig. 1. Experimental setup with a CMG balancing an inverted pendulum (IP). The pendulum's inclination angle and the CMG's rotation angle about the gimbal axis $\hat{\boldsymbol{g}}_g$ are denoted by ϕ and γ, respectively. Directions x,y and z are defined with respect to an inertial frame with z pointing vertical. Frames $\{\hat{e}_u, \hat{e}_v, \hat{e}_w\}$ and $\{\hat{\boldsymbol{g}}_s, \hat{\boldsymbol{g}}_t, \hat{\boldsymbol{g}}_g\}$ are defined fixed to the IP and the CMG respectively, with $\hat{e}_u$ and $\hat{e}_w$ pointing in the anterior direction and along the IP's longitudinal axis, respectively. Note that both frames fulfill the condition $\hat{e}_w \parallel \hat{\boldsymbol{g}}_g$ and $\hat{e}_v \parallel y$. Due to the gyroscopic effect, positive speeds about the CMG's $\hat{\boldsymbol{g}}_g$ axis (within the operation range) will produce moments on the IP with a positive component τ_{IP} about the $\hat{e}_v$ axis (i.e. in the sagittal plane).

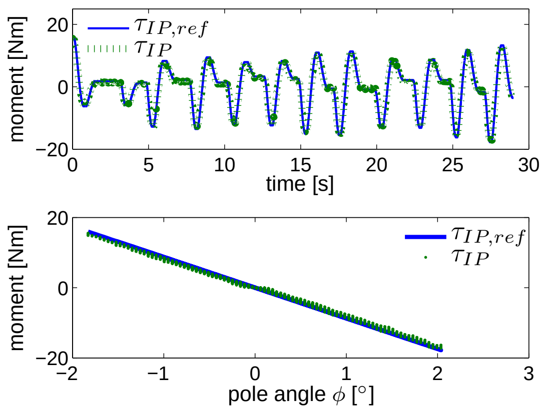

Fig. 2. Pendulum torque tracking over time with an RMS error of 0.55 Nm (top), and over angle illustrating the spring-like behavior (bottom).

REFERENCES

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