Improving Kinesthetic Haptic Renderings through a Frequency Partitioned Admittance Actuation Approach

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***Abstract*— This work introduces and provides preliminary results for a frequency partitioned admittance actuation approach which focuses on improving kinesthetic haptic renderings of admittance controlled haptic devices. More specifically, we aim to improve the position control bandwidth of admittance based haptic devices with our actuation approach. Doing so leads to improved device performance in terms of rendering low inertias and better output impedances. Finally, we present a one degree of freedom testbed to validate our proposed actuation approach and discuss our findings.**

I. Introduction

Admittance based kinesthetic haptic devices are well suited to rendering high forces and inertias as compared to impedance based haptic devices. They can render large impedances and forces in compact form factors. However, they have trouble rendering low impedances due to stability issues. The guidelines to improve the performance of these devices while rendering low impedances include methods like improving the position control bandwidth, adding virtual damping or limiting the delay [1][2][3]. We aim to improve this class of haptic devices through a frequency partitioning-based actuation approach for haptic and robotic applications.

The goal of this actuation approach is to achieve a higher position control bandwidth by splitting the workload of the command based on its frequency content between two actuators. To achieve this we employ a high-impedance, large motion amplitude actuator which provides low frequency motions. Additionally, we place a high impedance limited motion amplitude actuator in series such that actuator velocities sum at the output. This leads to a higher overall position control bandwidth and helps to overcome common stability limitations of high-gain position control systems.

We built a test bed to validate our hypothesized actuation approach using a harmonic drive as our low frequency high amplitude actuator and an ultrasonic motor as our high frequency low amplitude actuator as can be seen in Fig. 1. We designed a position controller for our harmonic drive with a validated position control bandwidth of 8 Hz as well as a position controller for our ultrasonic motor with a position control bandwidth >30 Hz. The ultrasonic motor works on the position error from the low frequency actuator, which naturally frequency partitions commands to each actuator. To validate our hypothesis, we test the command tracking performance, giving a chirp signal position reference to the system with the results displayed in Fig. 1 b. To assess device improvements, we choose to render an inertia because it is considered a metric of performance for admittance-type devices. We compare the performance of a typical admittance control approach, utilizing the harmonic drives position control loop alone, with that of our frequency-partitioned actuation approach. System stability is qualitatively checked by manually gripping the end effector and observing the behavior of the system. Testing with the harmonic drive alone, we find that the minimum inertia rendered is 0.01 Nm/rad/sec^2 whereas our actuation approach yield a minimum rendered inertia is 0.0055 Nm/rad/sec^2.

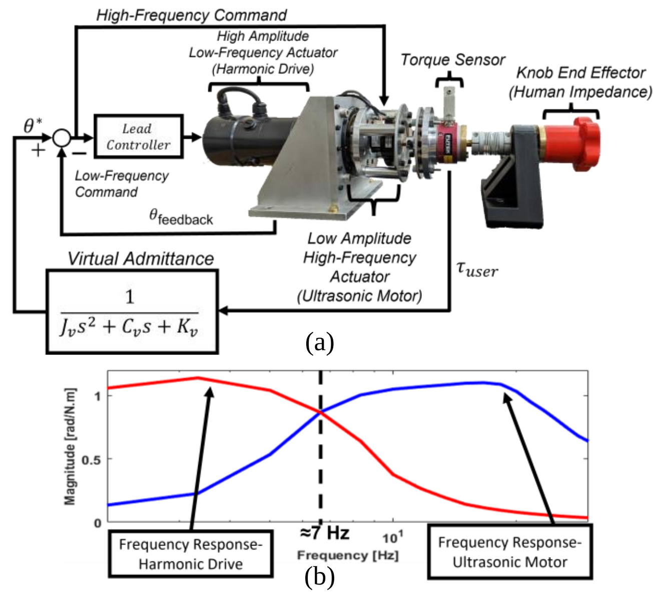

Figure 1. (a) Test bed for the frequency-partitioned admittance actuation. (b) Position command tracking frequency response plot of test bed

II. Conclusion & Future Work

The experimentally observed limit for the lowest inertia that can be rendered by the device is found to decrease by 45% with minimal tuning. We believe that with more tuning and testing, alterations to this actuation approach can yield even higher performance gains. Future work includes experimenting with variations of this actuation approach, further tuning of the current system, and performing an in-depth analysis of our actuation approach.

References

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