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I. INTRODUCTION

At the moment, performance evaluation of force feedback haptic devices presents a huge hurdle towards the general acceptance of haptic technologies by the public. The wide range of device mechanism and uses poses a seriously challenging task of evaluating how a device will perform.

Currently we evaluate the performance of devices based on respective quantifiable performance metrics for haptic systems. These haptic systems are analysed based on the device properties in the unpowered, powered, and interactive state [[Samur12]]. Still, we lack valuable quantitiative metrics that consumers could use to evaluate the quality of a device akin to the ??? for sound systems or ??? for televisions. Progress has been made to characterize the performance of specific devices based on their ability to perform in specified tasks that are fairly universal for haptic applications based on psychophysical evaluation test-beds. These widely accepted tasks can be partitioned into navigation, manipulation, and selection tasks.

Theoretically, a device's ability to perform well in these tasks should correspond to the overall usability of the device and thus, if quantified, could represent a means to discern a 'good' device from a 'bad' device. The usage of tried psychophysical evaluation techniques such as the fitts' tapping test[insert reference], peg in hole tests, etc., allow for the quantification of a device performance based on the users ability to perform a task of varying difficulty in a specified time.

These techniques have preliminarily been shown to be an effective means of evaluating two very different devices to perform a desired tasks. However, these evaluations are based on an ad hoc usage of the device workspace to perform the required tasks. In this study we seek to perform preliminary investigations into the dependency of device performance while performing the same task at different locations in the workspace.

We seek to evaluate the forces that a device may impart upon a user to decrease their ability to accomplish a simple

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yet universally navigational task of moving from one area of a workspace to another along a straight line. These forces will here on out be referred to as parasitic forces. The understanding of the nature of these parasitic forces will be generalized but will be further elaborated upon for the 2D case of a planar-five-bar mechanism. Finally, simulation will be compared to experimental results for the case of the five-bar-mechanism to determine if, and then to quantify by how much, the device performance for a standard navigational task is influenced by the trajectory.

The motivation for this study is to formalize the notion of parasitic forces resulting from the manipulator dynamics that can decrease performance as well as providing a groundwork for future studies to explore the reduction of parasitic forces using redundant mechanisms. While this may actually muddy the water in terms of providing a clear-cut answer to the problem of quantifying a haptic device, it may allow for users of pre-built devices to better utilise their existing workspace to increase device performance for specific tasks.

II. THEORETICAL BACKGROUND

To better familiarize the reader with the nature of the study, here we will elaborate on the background theory required for the study.

A. Fitts' Law and the tapping test

Drawing from Claude Shannon's seminal information theory work, *Mathematical Theory of Communication*[[Shannon48]], Paul Fitts hypothesised that the time it took for a human to accomplish a task was linearly proportional to the difficulty of the task [[Fitts54]]. The relationship Fitts devised is analogous to Shannon's Theorem [[Shannon48]] and is referred to as Fitts' Law:

$$MT = \frac{ID}{IP} \qquad (1)$$

Where, MT is the measured time, ID , is termed the index of difficulty and, IP, the index of performance. The index of difficulty is defined as,

$$ID = \log_2\left(\frac{2A}{W}\right) \qquad (2)$$

ID, is a way of non-dimensionalizing the difficulty of a movement task and corresponds to the ratio of the distance of an object, A, to the characteristic width of the object, W. Fitts required users tap a stylus between two targets of varying distance and size while measuring the time taken to perform the task. A linear regression was then performed on the data providing a line of best fit.

$$MT = a + bID \qquad (3)$$

The intercept, a, and slope, b, are empirically determined constants. The slope of this line, b, corresponds to the reciprocal of the Index of Performance, IP, and is assumed constant for the specific tool or device the user is operating with. The use of the base-2 logarithm in (2) allows for the ratio of distance to object width (corresponding to the associated difficulty of a task) to be expressed in units of bits. Rearranging equation (1) to solve for IP we see the Index of Performance, IP, can be expressed in units of $\frac{bits}{sec}$.

Ideally the intercept, a, is zero and deviations can be seen to indicate inaccuracies in the model though can also be attributed to by other additive effects that increase the measured time of a task but are not directly related to the task itself (i.e. button pressing to start and stop the measured time).

The Fitts' Law model of human response time as a function of task difficulty in 1D has held up well against scientific scrutiny and the results have been replicated and expanded upon for the 2D Steering Law [[insert references]] and even somewhat so for the 3D cases[[insert references]]. The validity of Fitts' Law as a tool for measuring the performance of haptic devices and virtual displays has also been demonstrated. For a more detailed introduction to the intricacies of Fitts' Law, including an attempt at a derivation of the equation from physical principals, the authors direct the reader to references [[insert citations]].

The form of Fitts' Law we will be using is reffered to as Shannon's variation as it is suggested by a direct analogy with Shannon's information theorem and is expressed as:

$$MT = a + b \log_2 \left(\frac{A + W_e}{W_e} \right) \qquad (4)$$

Where, W_e, is defined as the *Effective Target Width* [[Welford68]].

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TABLE I

AN EXAMPLE OF A TABLE

One	Two
Three	Four

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Fig. 1. Inductance of oscillation winding on amorphous magnetic core versus DC bias magnetic field

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V. CONCLUSIONS

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

APPENDIX

Appendixes should appear before the acknowledgment.

ACKNOWLEDGMENT

References are important to the reader; therefore, each citation must be complete and correct. If at all possible, references should be commonly available publications.

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