# Hierarchical pointing models for users operating under different speed accuracy strategies

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## 1 Introduction

A pointing model predicts the time it takes one to select a target with an input device *e.g.*, with a desktop mouse [**?**]. Classically, pointing time, also called movement time MT is modeled with Fitts' law [**?**, **?**, **?**]

$$\mathrm{MT} = a + b\log_2(1 + \mathrm{D}/\mathrm{W}), \tag{1}$$

$$= a + b\,\mathrm{ID} \tag{2}$$

where D and W are geometric parameters (size and distance of the target), ID is the index of difficulty, and $a$ and $b$ are the estimated parameters of the linear model. Fitts' law plays an important role in HCI because pointing is a ubiquitous interaction, namely when evaluating input techniques [**?**] and when designing interfaces [**?**].

Movement modeling has advanced greatly since Fitts' seminal work [**?**] and the introduction of Fitts' law in HCI [**?**]. While Fitts' law only describes endpoints, motor control models now propose description of entire trajectories produced during pointing tasks [**?**, **?**, **?**, **?**, **?**]. While Fitts' law only describes means of movement times, several models now describe distribution of movement times using asymetric distributions [**?**, **?**, **?**, **?**, **?**, **?**].

One avenue that has seen less effort in comparison is models of pointing when users operate under different speed accuracy strategies. These models become needed when one wants to describe how users point with various incentives. One notable exception is the Weighted Homographic (WHo) model of Guiard and Rioul [**?**], which describes pointing data in a strategy versus effort space. The WHo model was for example recently used as a low level control module in hierarchical models of pointing [?, ?], where a high level controller decides on the pointing strategy, being more cautious if the cost to recover from errors is higher.

The WHo model however does not describe distribution of data. Instead, it describes the convex hull of *best possible* performing data points. In Guiard and Rioul's work, the WHo model is fitted on the best 10 aggregates, out of 400! Hence, works that use these models use an overly optimistic model of movement. The goal of this work is to suggest a simple model for distribution of movement times that incorporates user strategies.

# 2 Background

## 2.1 Participant strategies and the effective index of difficulty

Fitts' law experiments claim to investigate the speed accuracy tradeoff. To do so, the experimenter manipulates accuracy by modifying W and observes speed of the response by measuring MT in Equation 1. However, it is well known that this manipulation is imperfect: users underutilize *easy* (low ID) targets and over-utilize *hard* (high ID) targets [?, ?]. A solution, due to Crossman and popularized in HCI by Mackenzie [?] is to compute an effective index of difficulty $\mathrm{ID}_e$ as a post-hoc adjustment of difficulty as a function of the effectively measured standard deviation of endpoints $\sigma$

$$\begin{aligned} \mathrm{MT} &= a + b\,\mathrm{ID}_e && (3)\\ &= a + b\,\log_2\left(1 + \frac{D}{4.133\sigma}\right). && (4) \end{aligned}$$

Several researchers, beginning with Mackenzie [?] have investigated how people perform Fitts' task when instructed to emphasize either speed or accuracy. As expected, participants are able to modify their strategies, as reflected by changes in $\mathrm{ID}_e$ for the same ID level. For example in Mackenzie's experiment, on average participants erred up to 20% in the speed condition, but erred close to 0% in the accuracy condition. Guiard [?] later performed a similar experiment, but without explicit width (participants had to aim towards a line) with 5 instructions (Ultra Fast, Fast, Balanced, Accurate, Ultra Accurate). Other similar experiments include [Ufuk, Wolfgang, Shota].