
An Extensible Platform for the Interactive Exploration of Fitts' Law and Related Movement Time Models

Martin Schedlbauer

Computer Science
University of Massachusetts
Lowell, MA 01854 USA
mschedlb@cs.uml.edu

Abstract

This paper describes a new software platform for the interactive exploration of human performance models such as Fitts' law. The software is written in Java and provides a flexible environment for HCI research and education. Its distributed, object-oriented architecture provides a framework for exploring new performance models, task types, and selection modes.

Keywords

Fitts' law, HCI education, human performance modeling, input device evaluation

ACM Classification Keywords

H.5.2 [INFORMATION INTERFACES AND PRESENTATION]: User Interfaces – Input devices and strategies.

Introduction

While many *ad hoc* utilities have been developed for evaluating input devices and modeling cursor positioning time, except for the *Generalized Fitts' Law Model Builder* [5] and the more recent *WinFitts* program from the University of Oregon [2][11], few of these utilities are *bona fide* research platforms. A

Copyright is held by the author/owner(s).

CHI 2007, April 28 – May 3, 2007, San Jose, California, USA

ACM 978-1-59593-642-4/07/0004.

standardized, extensible research platform would allow HCI researchers to compare experimental results meaningfully and share experimental configurations. To facilitate our studies and to provide a general research platform to the scientific community the *Movement Time Evaluator* (MTE) has been constructed to meet this need.

MTE is a configurable tool for exploring input device characteristics as well as rapidly evaluating performance models. It is written in Java and is constructed on an extensible object-oriented and pattern-based framework. MTE has a comprehensive graphical user interface that allows researchers to configure their experiments and interpret results interactively. It allows researchers to compare their own models immediately to Fitts' law [3] and the variations defined by Accot and Zhai [1], Kvålseth [7], MacKenzie [5], and Meyer *et al.* [6].

MTE extends Soukoreff and MacKenzie's platform by adding bivariate pointing tasks, probe corrections [4], additional performance models, non-stationary targets, soft keypads, dynamic configurability, and movement microstructure evaluation. As a result, MTE presents a new research platform which allows input device investigators to conduct standardized experiments and to directly compare device characteristics, performance and usability. Silfverberg, MacKenzie, and Kauppinen [9] lament the fact that between-study comparisons are not addressed by ISO9241 and that unified test conditions only provide high-level comparisons of research results. Douglas, Kirkpatrick, and MacKenzie [2] "adamantly assert caution in comparing results across experiments." They argue that "it is critical that exactly the same experimental design, task

environment, instructions and data analysis be given" and that "given these limitations, it is useful to have standardized software." Sharable experimental configurations and results are required to carry out between-study statistical analyses. MTE provides a framework upon which to build a database of reference conditions, configurations, and eventually experimental results.

The software is open source and is distributed under the GNU Public License (GPL). An executable version that runs under Java 5 as well as the full source code is available for download [8].

Platform Capabilities

MTE is touch-screen enabled and supports a multitude of indirect input devices, including mice, joysticks, touchpads, keypads, and trackballs. The input devices are supported through the universal mouse driver of Windows XP and are connected via a USB port.

All of the interactions, including all cursor movements, region selections, clicks, cursor traces (trails), and selection errors are recorded using either Java object serialization or XML and can be exported into comma-separated text files (CSV format) so that importing into Excel, and the "R" statistics package is facilitated.

Basic statistical analysis built into the platform facilitates rapid evaluation of experimental results and interactive exploration of models. MTE implements standard descriptive statistics (mean, range, and standard deviation), Pearson product moment correlation, linear regression, as well as configurable scatter plots and distribution graphs. In addition, the raw data, the trajectories and kinematics of individual

acquisition movements, and the spatial distribution of selections can be viewed so that the kinematic micro-structure and accuracy characteristics of different input methods can be studied. Also, the researcher can view a tabular comparison of the correlation coefficients and throughput measures of various movement time models, including new models constructed by the researcher. The linear regression coefficients and the correlation coefficient can be computed either on the observed or averaged values.

MTE's architecture is based upon a client/server model. The platform can be controlled remotely, allowing a researcher to observe and direct the experiment from one workstation while the participant interacts with the software on another workstation. Connectivity is through TCP/IP, and therefore researcher and participant can be separated by any distance facilitating remote data collection.

Experiment Configuration

The configuration of experiments is a two-step process. First, the researcher interactively constructs and saves an experimental configuration file that specifies session invariant parameters, including target extent, target shape (rectangular, oval, text, oscillating, soft keypad), home region placement (center of screen, random, coordinate system origin, or none), target position distribution (uniformly random, fixed positions, or reciprocal), feedback (auditory and visual), number of repetitions, task type (point-and-click versus click-and-drag), information recorded (movement velocity, cursor path, and selection errors). Second, before the researcher runs an experiment, a configuration file is selected from a list of stored setups. Prior to the beginning of an experimental trial, the researcher can

enter trial-specific factors such as subject information, environmental factors, distance from screen, physical screen size, probe width, or any relevant ad hoc information. The test subject is then presented with an optional home region and a target. Upon successful selection of the home region, the timing of the movement starts. Once the target region is hit, the elapsed time, along with the selection end point, the cursor path, the distance traveled, and any selection errors, are recorded.

MTE can be extended by adding new static or dynamic (moving) shape types, target position distributions, movement time models, and data export formats. Many of these extensions require minimal programming. HCI researchers should find the easy integration of new performance models beneficial during hypotheses testing.

Tour of an Experiment

The use of a tool is best explained through a guided example. For instance, one might want to determine whether target selection using finger touch is more or less effective than input with a trackball. For this purpose, an experiment is defined that presents subjects with several differently sized targets at varying positions. The experiment configuration dialog allows us to specify the target geometry and shape, target position distribution, number of repetitions, whether to hide the home region upon start, whether to display the target immediately or delay until the home region is selected, and the type of task (point-and-click versus drag). Once configured, the experiment is run with a number of subjects. For each subject, pertinent data such as gender, age, handedness, and height can also

be optionally recorded. Figure 1 shows a screen shot of an actual trial run.

After the raw data is gathered, the subject specific data sets can be merged into a single combined data set for exploration. Data sets can be explored in their raw form or in a “scrubbed” form in which data is binned (grouped and averaged) and outliers are removed. Scatter plots and a sortable table of the raw data aid in the detection of outliers.

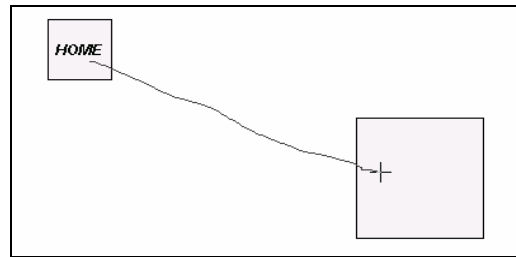


Figure 1. Acquisition of a square target. Trajectory of the movement path is shown in this configuration.

Figure 2 shows a scatter plot of the raw data for an experiment session along with the linear regression equation for Fitts' law. Movement time (MT) is along the Y axis and the Index of Difficulty (ID) is along the X axis. The tool allows any recorded parameter to be plotted against any other recorded parameter, e.g. amplitude against movement time or target angle against ID . To facilitate the comparison of different experiments, multiple data sets can be plotted side-by-side or overlaid. Figure 3 shows a scatter plot that contains both the touch and the trackball data.

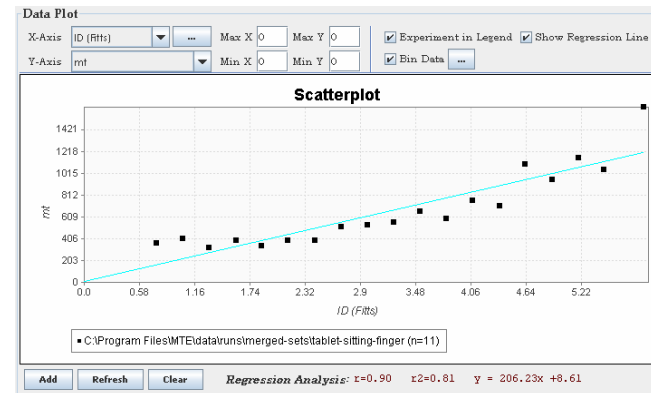


Figure 2. Scatter plot of ID versus MT with correlation coefficient and linear regression equation.

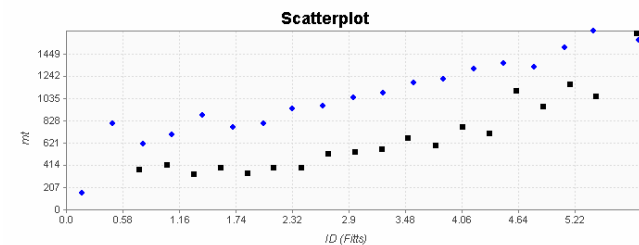


Figure 3. Scatter plot of ID versus MT of two runs of the same experiment, one using touch input and one using a trackball.

Figure 4 summarizes the correlation results and throughput calculations for several movement time models. It shows the correlation coefficient (R) and the coefficient of determination (R^2) for each model using the Euclidean distance between the targets as the amplitude as well as the length of the cursor trajectory. Furthermore, the movement model panel displays minimum, maximum, and mean ID and MT . The models can be supplied the effective width W_e [5] or the width along the approach trajectory instead of the nominal

width along the horizontal and researchers can immediately see the effect on the correlation. Additionally, the width used in the model calculations can be increased by the width of the probe as proposed by Hoffmann and Sheikh [4].

Model Comparison								
	Simple	Fitts	Welford	Shannon/	Meyer et al.	Kvalseth	Accot-Zhai	ID*2
R (A, W)	0.82	0.97	0.97	0.96	0.92	0.82	0.95	0.85
R (D, W)	0.90	0.97	0.98	0.97	0.95	0.90	0.97	0.85
R2 (A, W)	0.67	0.95	0.95	0.92	0.85	0.67	0.90	0.73
R2 (D, W)	0.82	0.94	0.96	0.94	0.90	0.82	0.95	0.73
1/b	34.18	5.09	4.02	3.49	3.77	34.18	3.75	5.07
TP-A (bps)	5.86	2.77	2.09	2.21	2.03	5.86	2.33	1.09
TP-D (bps)	7.44	3.04	2.34	2.44	2.28	7.44	2.56	1.24
Mean (ID)	7.20	3.40	2.57	2.71	2.49	7.20	2.86	1.34
Max (ID)	25.13	5.65	4.68	4.71	5.01	25.13	4.88	3.69
Min (ID)	0.05	0.01	-0.87	0.07	0.22	0.05	0.08	0.03
Mean (MT)	1,227.90	1,227.90	1,227.90	1,227.90	1,227.90	1,227.90	1,227.90	1,227.90
Max (MT)	5,128.00	5,128.00	5,128.00	5,128.00	5,128.00	5,128.00	5,128.00	5,128.00
Min (MT)	151.00	151.00	151.00	151.00	151.00	151.00	151.00	151.00
Intercept	1,021	559	585	436	531	1,021	441	954
Slope	29	197	249	286	265	29	267	197

Figure 4. Table showing the fit of various models. The table also contains the average tested ID, the calculated device throughput (ratio of MT over ID), and the linear regression equation's intercept and slope values.

To better understand the kinematics of indirect input devices, researchers can visualize the trajectory paths for each experiment. The plot in Figure 5 contains the starting position of the movement, the position at which the target was successfully acquired and the actual path traveled. A different view of the microstructure of the movement is shown in Figure 6 as a plot of the speed along the trajectory path. Note how the movement is initially accelerating, and then slows down as the cursor moves toward the target.

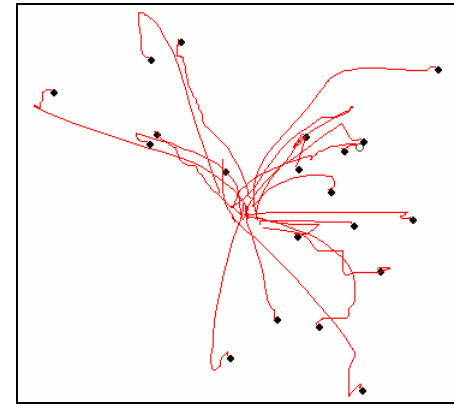


Figure 5. Plot of the actual trajectory of the trackball movement for some of the target acquisitions.

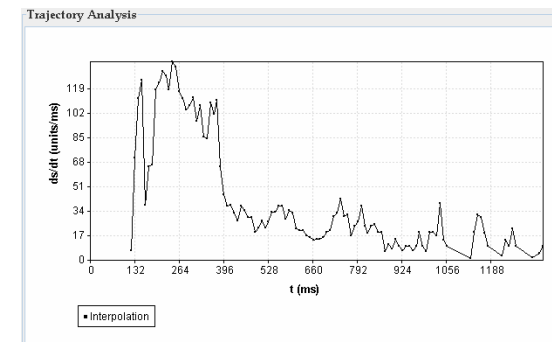


Figure 6. Graph of time versus speed for all trackball movements to the same targets averaged over all subjects. The graph starts at an offset which represents the reaction time before movement toward the target commences.

Conclusion

MTE represents a configurable environment for the interactive exploration of cursor positioning models. Aside from its applicability to input device research, it is

well-suited to HCI education because it allows students to discover performance models such as Fitts' law empirically. While the basic statistical mechanisms built into MTE are useful for exploration and discovery, they are limited but easily augmented by specialized statistics packages.

In our experience, researchers prefer using pre-built tools for experimentation rather than constructing their own. As an example, MTE was recently used by a team of graduate students that sought to evaluate a novel input device for use in assistive technology settings. They stated that if it had not been for the availability of MTE, they would not have conducted the experiments because the development of the necessary experimental software would have been far too time consuming. The use of MTE allowed them to conduct usability tests rapidly and establish the performance characteristics of the novel input device.

Acknowledgements

The author wishes to thank the students and faculty that participated in experiments and have used MTE in their work as well as Dr. Jesse Heines for his helpful comments in reviewing early drafts.

References

- [1] Accot, J, Zhai, S. Refining Fitts' law models for bivariate pointing. In *Proc. CHI 2003*, ACM Press (2003), 193-200.
- [2] Douglas, S., Kirkpatrick, A., & MacKenzie, S. Testing pointing device performance and user

assessment with the ISO 9241, Part 9 Standard. In *Proc. CHI 1999*, ACM Press (1999), 215-220.

- [3] Fitts, P. M. The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology*, 47(1954), 381-391.
- [4] Hoffmann, E. R., Sheikh, I. Finger width corrections in Fitts' Law: Implications for speed-accuracy research. *Journal of Motor Behavior*, 4 (1991), 259-262.
- [5] MacKenzie, S. Movement time predictions in human-computer interfaces. In *Readings in Human-Computer Interaction, 2nd Edition*, Morgan Kaufman (1995) 483-493.
- [6] Meyer, D., Abrams, R., Kornblum, S., Wright, C., & Smith, J. Optimality in Human Motor Performance: Ideal Control of Rapid Aimed Movements. *Psychological Review*, 3 (1995), 340-370.
- [7] Kvålseth, T. An Alternative to Fitts' Law. *Bulletin of the Psychonomic Society*, 5 (1980), 371-3.
- [8] Schedlbauer, M. Movement Time Evaluator 2.1.3, <http://www.cs.uml.edu/~mschedlb/mte>.
- [9] Silfverberg, M., MacKenzie, I. S., & Kauppinen, T. An isometric joystick as a pointing device for hand-held information terminals. In *Proc. Graphics Interface 2001*, Canadian Information Processing Society (2001), 119-126.
- [10] Soukoreff, W., and MacKenzie, I. S. Generalized Fitts' Law Model Builder. In *Proc. CHI 1995*, ACM Press (1995), 113-114.
- [11] University of Oregon HCI Research Laboratory. WinFitts: Two-dimensional Fitts Experiments on Win32. <http://www.cs.uoregon.edu/research/hci/research/winfitts.html>.