In *Proc. IEEE Virtual Reality Conference 2003*, March 22-26, Los Angeles

Human Movement Performance in Relation to Path Constraint

The Law of Steering in Locomotion

IBM Almaden Research Center, USA
zhai@us.ibm.com

Linköpings Universitet, Sweden
rogwo@ikp.liu.se

Abstract

We examine the law of steering – a quantitative model of human movement time in relation to path width and length previously established in hand drawing movement – in a VR locomotion paradigm. Participants drove a simulated vehicle in a virtual environment on paths whose shape and width were manipulated. Results showed that the law of steering also applies to locomotion. Participants' mean trial completion times linearly correlated (r^2 between 0.985 and 0.999) with an index of difficulty quantified as path distance to width ratio for the straight and circular paths used in this experiment. Their average mean and maximum speed was linearly proportional to path width. Such human performance regularity provides a quantitative tool for 3D human machine interface design and evaluation.

1. Introduction

$$MT = a + b \log_2 (A/W+1) \qquad (1)$$

W

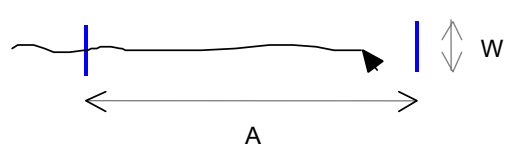


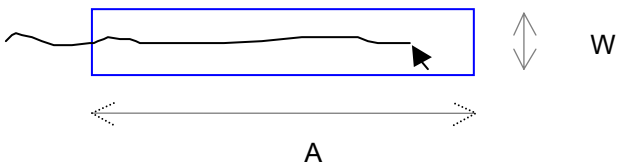
Figure 1. A two goal-passing task also follows Fitts' law

$log_2 (A/W+1)$ $A/W \ln(2)$

$$MT = a + b\, A/W \qquad (2)$$

$$ID = \int_c \frac{}{W \quad s} ds$$

a b



a b

Figure 2. Steering through a tunnel follows the law of steering

$$T_c = a + b \int_c \frac{ds}{W \quad s}$$

$$v \quad s \quad = W \quad s \quad \tau \qquad (4)$$

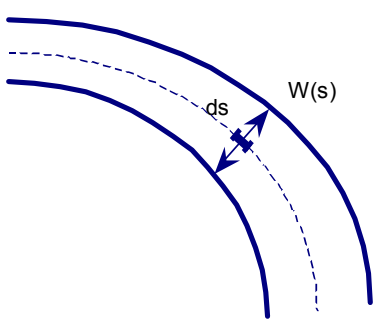


Figure 3. Generalized steering task

a, b τ

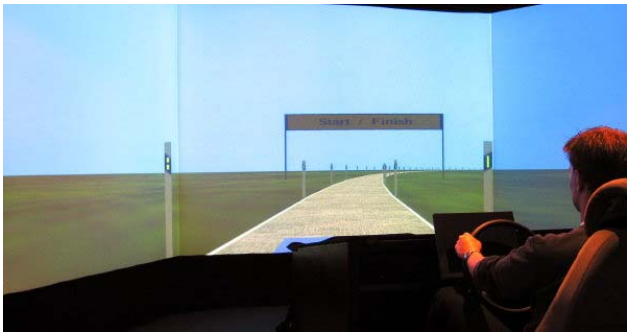


Figure 4. Driving in virtual world

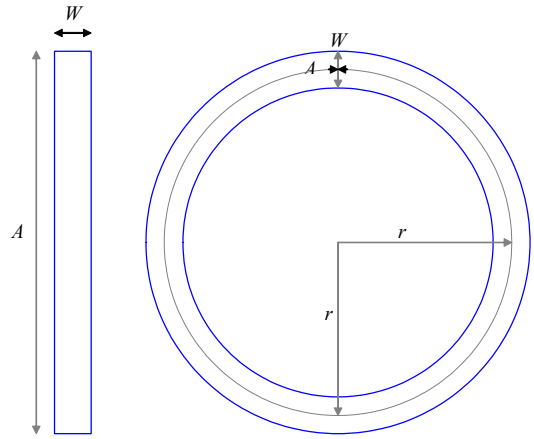


Figure 5. Two types of paths used in the experiment

2. Method

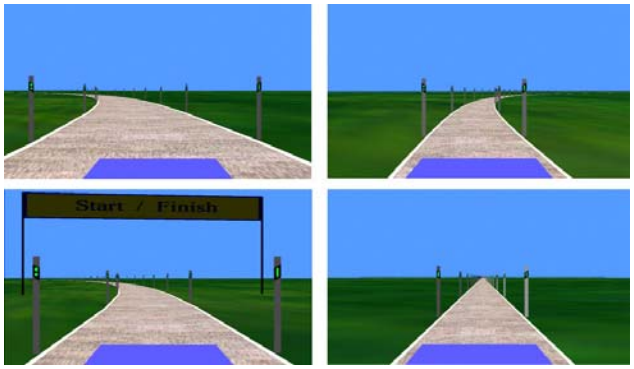


Figure 6. Screen shots of the simulator's central screen. Top left: wide width left turning circular path. Top right: narrow right turning path. Bottom left: medium width straight path approaching finishing line. Bottom right: narrow straight path.

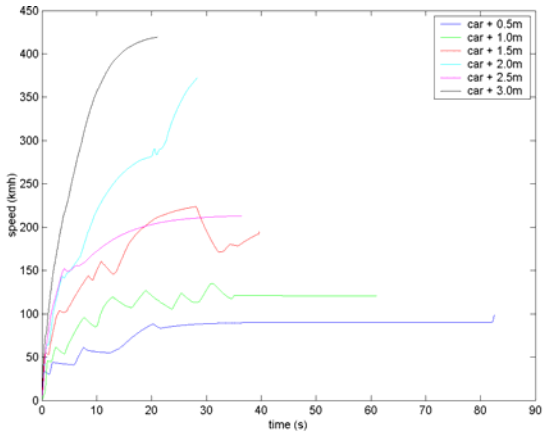


Figure 7. Sample speed-time trajectories (one participant, Block 2, Right turning path)

3. Results

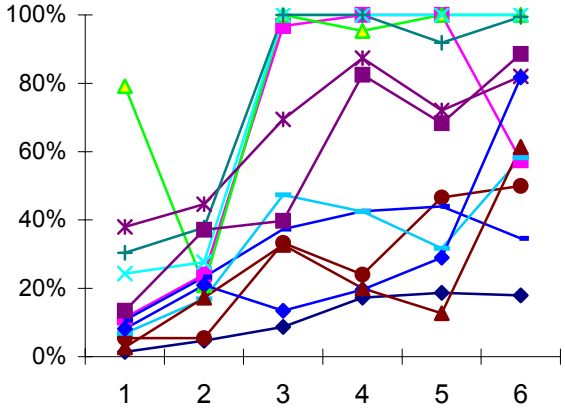


Figure 8. Gas pedal maximum magnitude of all participants in 6 path widths in one block

3.1. Trial Completion Time

Straight Path

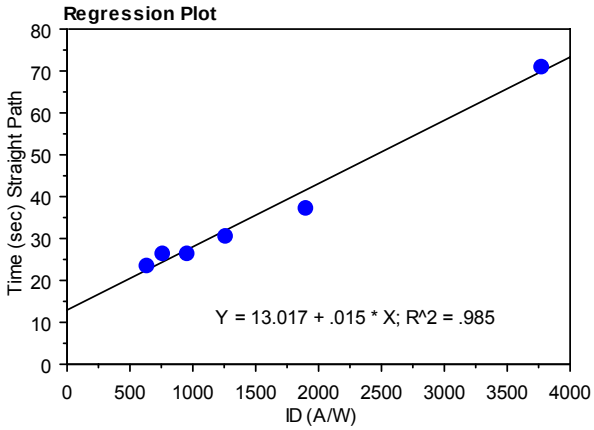


Figure 9. Trial completion time vs. index of difficulty in the straight path condition

r^2

Right Circular Path

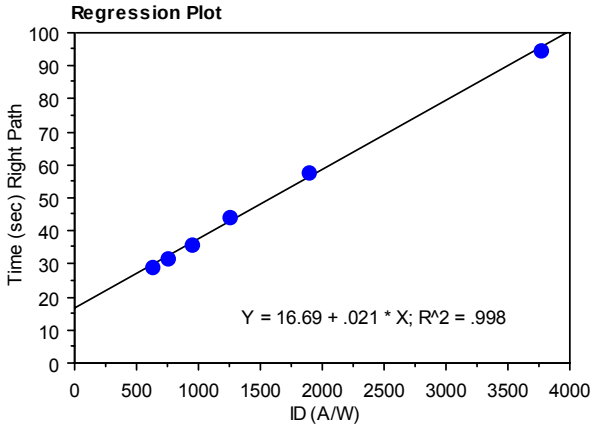


Figure 10. Trial completion time vs. index of difficulty in the right circular path condition

Left Circular Path

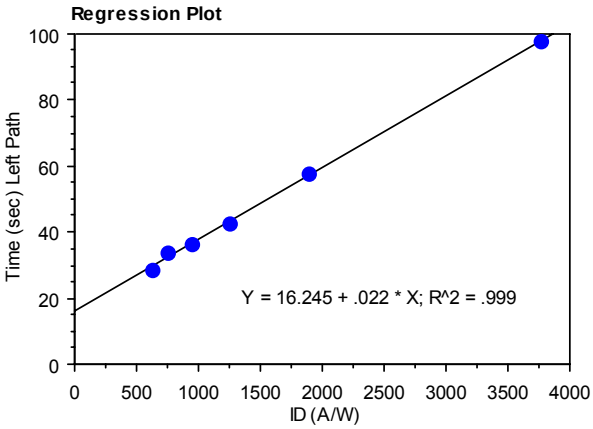


Figure 11. Trial completion time vs. index of difficulty in the left circular path condition

3.2. Maximum Speed

W

W

$r^2 \geq$

r^2

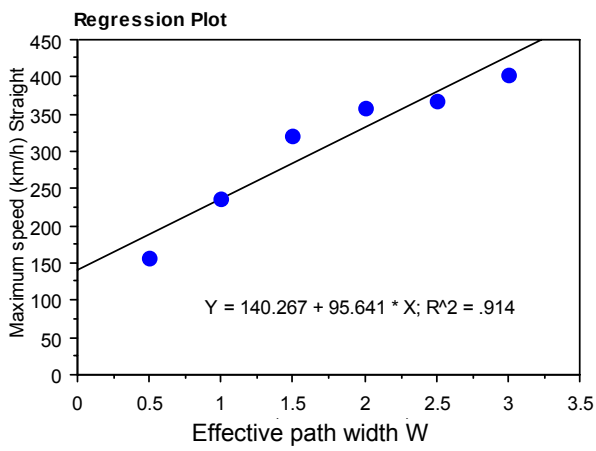


Figure 12. Mean maximum speed vs. path width, straight path

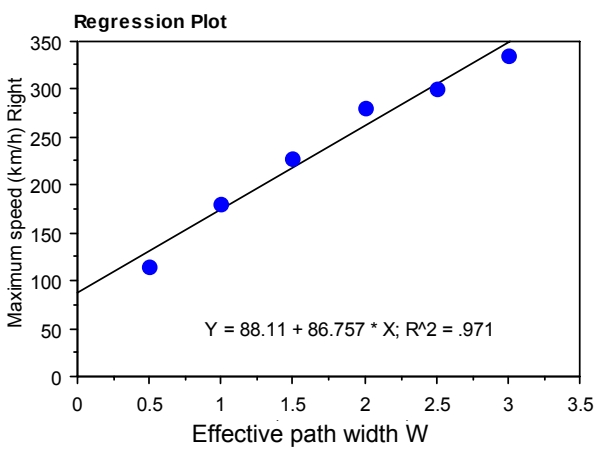


Figure 13. Mean maximum speed vs. path width, right circular path

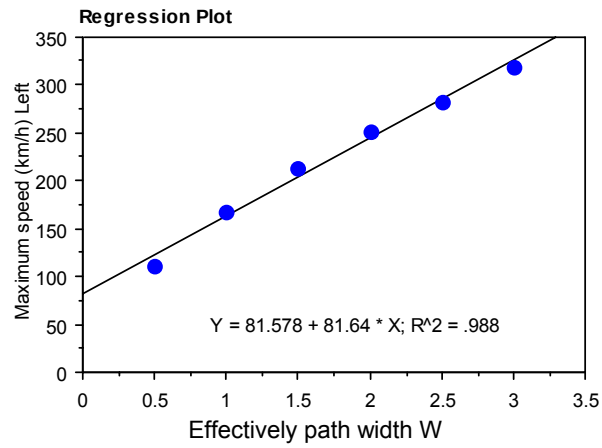


Figure 14. Mean maximum speed vs. path width, left circular path

3.3. Error Rate

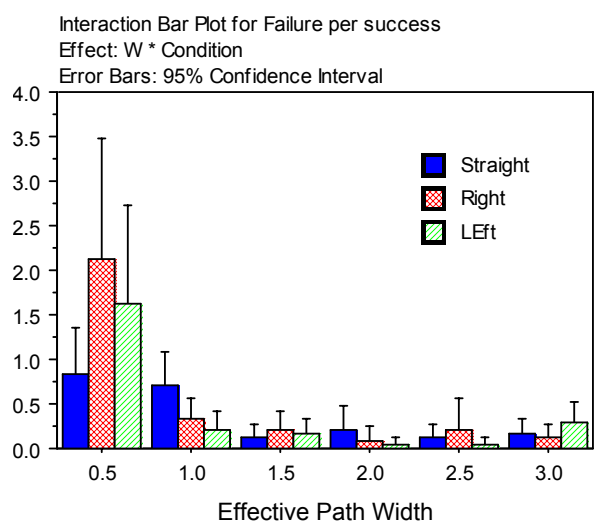


Figure 15. Number of failed attempts per success trial

3.4. Lateral Deviation

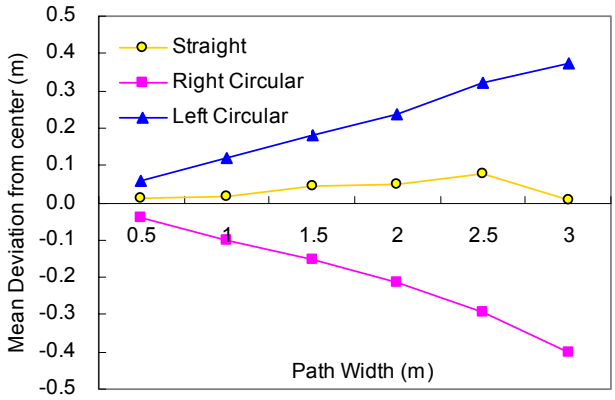


Figure 16. Deviation from the centerline, negative = right

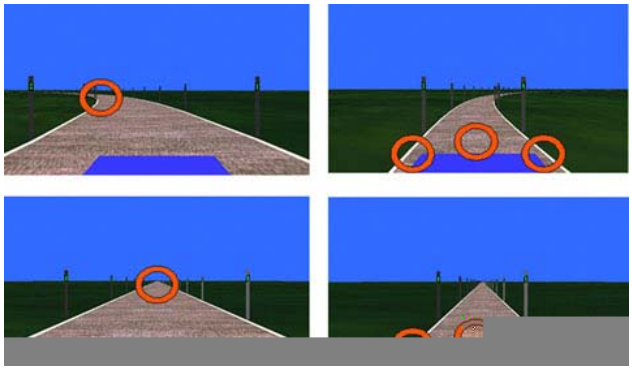


Figure 17. Subjective visual attention tendency

3.5. Attention behavior

4. Discussion, Conclusion and Application