Motion-Pointing: Target Selection using Elliptical Motions

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There are situations when selecting an item by pointing is (very) difficult
Solution:
Selecting by matching a motion

• For each target
  – Display an animated point called the *driver*
  – Drivers follow an elliptical trajectory
  – Each driver has a unique motion

• To select a button
  – Imitate its driver motion
Rationale

• Why motion?
  – Motion is visible: no need to learn
  – No need to look at the pointer’s cursor
    • Proprioceptive feedback is sufficient

• Why Elliptical?
  – Natural:
    • Periodical harmonic motion, minimizes the dissipation of mechanical energy, recycles potential energy into kinetic energy and vice versa
    • Ability of people to spontaneously couple themselves with an external oscillator
  – Stationary: can do it almost in place
Formal Setting

- Amplitude
  - A
- Aspect ratio
  - \( R = \frac{b}{A} \)
- Angle
  - A
- Period
  - P or Frequency = \( \frac{1}{P} \)
- Direction
  - CW/CCW
Formative Study

- What are the human capabilities?

- F in \( \{1, 4/3, 2, 4\} \) Hz
- A in \( \{5, 10, 20\} \) pixels
- R in \( \{0, 0.3, 0.6, 1\} \)
- \( \alpha \) in \( \{0, 45, 90, 135\} \)°
- D in \{CW, CCW\}

- 6 participants
  - 384 trials per session
  - 10s of recording,
  - approx. 1h20mn overall time

- 64Hz refresh rate

- Recorded:
  - Time
  - Driver X, Y
  - Pointer X, Y

- 640 samples per trial
Analysis

Spatial Analysis: Ellipse Fit
• On a 100 samples moving window
• Computes:
  – A, R, α (no F or D)
• StdDev of Fit
• StdDev of A, R, α

Temporal Analysis: Phase Error
• Phase of 1D signal:
  – +1 at each local max
  – -1 at each local min
  – Interpolated in between
• Phase Difference:
  – Phase(X)=Phase(Driver X) – Phase (Pointer X)
  – Phase(Y)=Phase(Driver Y) – Phase (Pointer Y)
• Phase Distance:
  – Dist(Phase(X),Phase(Y))
Spatial Analysis: Ellipse Fit

(a) Quality of fit
(b) Variation of angle

(e) Quality of fit averaged
(f) Variation of angle av.
Spatial Analysis: Ellipse Fit (cont.)

(c) Variation of amplitude
(d) Variation of ratio

(g) Variation of amplitude av.
(h) Variation of ratio av.
Temporal Analysis: Phase Error

(a) Phase error for one trial.  
(b) Average phase error.
How to Match?

• Use the relative movements (dx, dy)

• Euclidean Distance (ED)
  \[ f(u, d) = \sum_{i\in[t-w,t]} ((ux_i - dx_i)^2 + (uy_i - dy_i)^2) \]

• Normalized Euclidean Distance (NED)
  \[ f(u, d) = \sum_{i\in[t-w,t]} \left( \frac{ux_i}{||u||} - \frac{dx_i}{||d||} \right)^2 + \left( \frac{uy_i}{||u||} - \frac{dy_i}{||d||} \right)^2 \]

• Correlation (C)
  \[ f(u, d) = \sum_{i\in[t-w,t]} ((ux_i \times dx_i) + (uy_i \times dy_i)) \]

• NED on a 2s time window best
The Move&Stroke Technique

• Matching is not 100% accurate
  – 1) matching
  – 2) confirmation on 4best
1) idle mode, wait for rotations
2) motion mode (no click)
3) Start stroke (stop motion)
4) drag direction to confirm
5) Release stroke: selection
Move & Stroke

Idle

Move

Stroke
Properties of Move&Stroke

1. Fixed Gaze
2. Visibility and learnability
3. Robust to matcher errors
4. Simple and intuitive activation
5. Cancelation
6. Low visual clutter
Summative User Study

• Interested in measuring the throughput
  – In bits per second
• With B bits, we can select $2^B$ buttons
• B in \{1, 2, 3, 4, 5, 6\}
  – 2, 4, 8, 16, 32, 64 buttons
• Times measured:
  – Idle->tracking (IT) no effect on B
  – Tracking->Selection (TS) significant effect on B
  – Selection->Idle (SI) no effect on B
• Ratio has a significant impact on TS performance
  – $R=0$ easier than $R=0.5$
Results

(a) Tracking time (seconds).
(b) Average tracking time (seconds).
(c) Average correctness (ratio).
Practical Use
Conclusion

• Humans are apt at reproducing oscillatory motions using a mouse/tablet/pad/finger
• Move&Stroke supports target acquisition with a time proportional to the number of bits
  – Practical technique for unreachable targets

• Improves with a bit of training
• Matcher should be improved
• Oscillatory motions are not produced only by the hand