iType: Using Eye Gaze to Enhance Typing Privacy

Zhenjiang Li\textsuperscript{1}, Mo Li\textsuperscript{2}, Prasant Mohapatra\textsuperscript{3}, Jinsong Han\textsuperscript{4}, Shuaiyu Chen\textsuperscript{4}

\textit{CityU}\textsuperscript{1}, \textit{NTU}\textsuperscript{2}, \textit{UC Davis}\textsuperscript{3}, \textit{XJTU}\textsuperscript{4}
Wearables

- Accelerometers
- Gyroscope
- Ambient light sensor
- Heart rate sensor
- Magnetometer
- GPS
- ...

Extend beyond timing ➔ daily life, e.g., fitness, exercise, business, etc.

However

Explicitly typing sensitive info.
• Password
• Personal data
• Security code
• ....

Continuously sense hand moves
• Accelerometers
• Gyroscope
• ....
Wait a moment ...

- Touch ID
- But

Explicit Textual-Input is unavoidable
Our idea for protection

• **Eye gaze** for input
  • **Front** camera

• **Secure**
  • **Back**
    • A keyboard
  • **Front**
    • Difficult to distinguish
    • Keyboard layout may change
iType framework

3. Noises from device motions

1. Unreliable mobile gaze tracking

2. Lack of true text-entry value in error correction

Front Camera

Accelerometers

Frame Selector

Password Assembler

Keyboard Rearranger

AcCELEROMETERS

Gaze Engine

Video Stream

Gaze Tracker

iType Engine

Button Selector

Group Centroid Estimator

Transitional Gaze Remover

Keystroke Detector

Typing Error Corrector

Virtual Button

Flying Button

Joint Decoder

Enhance Layer

Keyboard Rearranger

Typing Error Corrector

Joint Decoder

Password Assembler

Enhance Layer
Unreliable mobile gaze tracking

Problem statement:

Gaze tracker training [2]:

Data collection for model learning

Neural Network-based Gaze Predictor

Download model

iShadow platform

Input: image

Output: gaze coordinates

Unreliable mobile gaze tracking

• Problem statement:

For mobile devices:
Unreliable mobile gaze tracking

• Accuracy we need?

![Graphs showing error in gaze tracking for Smartphone and Tablet](image-url)
Unreliable mobile gaze tracking

- Observations

Unreliable tracking
Unreliable mobile gaze tracking

• Formal description

Less

More

Min. samples to achieve certain confidence?

• Solution overview (n gaze points)

\[
(\bar{x} - \frac{t}{\sqrt{n}} S_x, \bar{x} + \frac{t}{\sqrt{n}} S_x)
\]

At least \(1 - \alpha\)

\[S_x^2 = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2\]
Keystroke detection

• When to start?

• KL divergence  \( Q = \{q_i\} \) and \( P = \{p_i\} \)

\[
D_{KL}(Q \| P) = \sum_i q_i \log_2 \frac{q_i}{p_i}
\]
Keystroke detection

- **When to start:**
  - KL divergence
- **When to stop:**
  - Approximation

\[
\begin{align*}
\text{(a)} & \quad G_1 \\
\text{(b)} & \quad G_2 \\
\text{(c)} & \quad G_3 \\
\end{align*}
\]

\[
\begin{align*}
\text{Window size } w &= 12 \\
\end{align*}
\]
Other modules

• **Input error correction**
  • Joint decoding

• **Frame selection**
  • Sensor-assisted
Evaluation

• Overall performance

Individual keystroke:

- **Accuracy**
  - Static: 97%
  - Dynamic: 89%

- **Latency**
  - Static: 2.0s
  - Dynamic: 2.6s
Takeaways

1. On-going trend
   a) More & powerful sensors

2. Dual aspects
   a) Beneficial to usage
   b) Potential privacy issue

3. Challenges for iType
   a) Unreliable mobile gazing
   b) Unknown ground truth
   c) Device motions