A multimodal interface for chess

How we made people gesticulate and scream at their computers

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The Idea

Remember this?

Figure: Wizard's Chess, Harry Potter and the Philosopher's Stone

The Idea 2

Know this feeling?

Figure: Some stock image of an hand holding a chess piece.

Before that

We have to get from here...

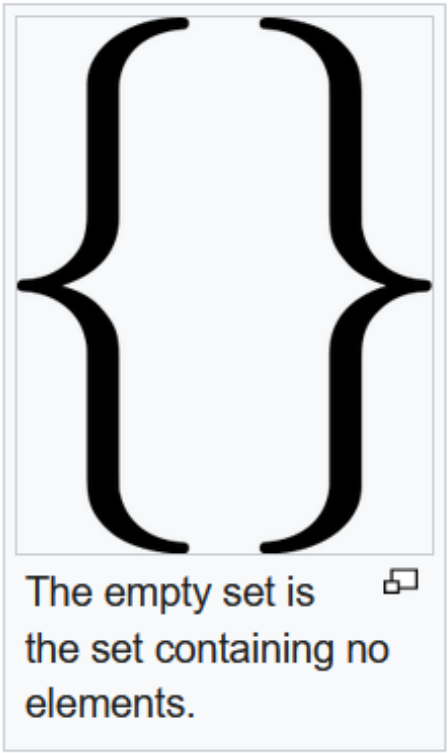


Figure: What we have.

To here!

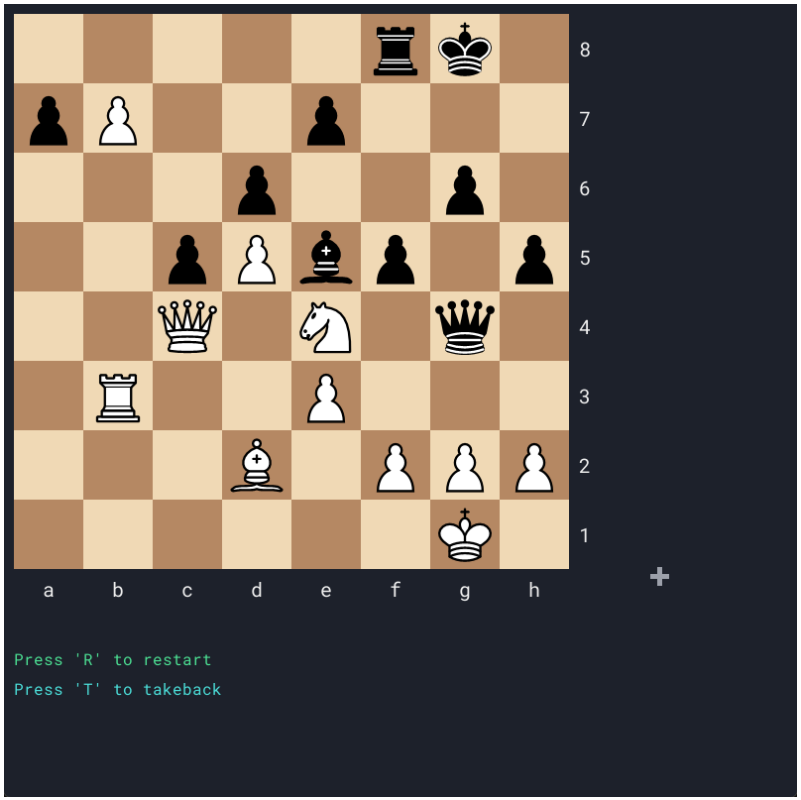


Figure: What we want.

We need some OOP

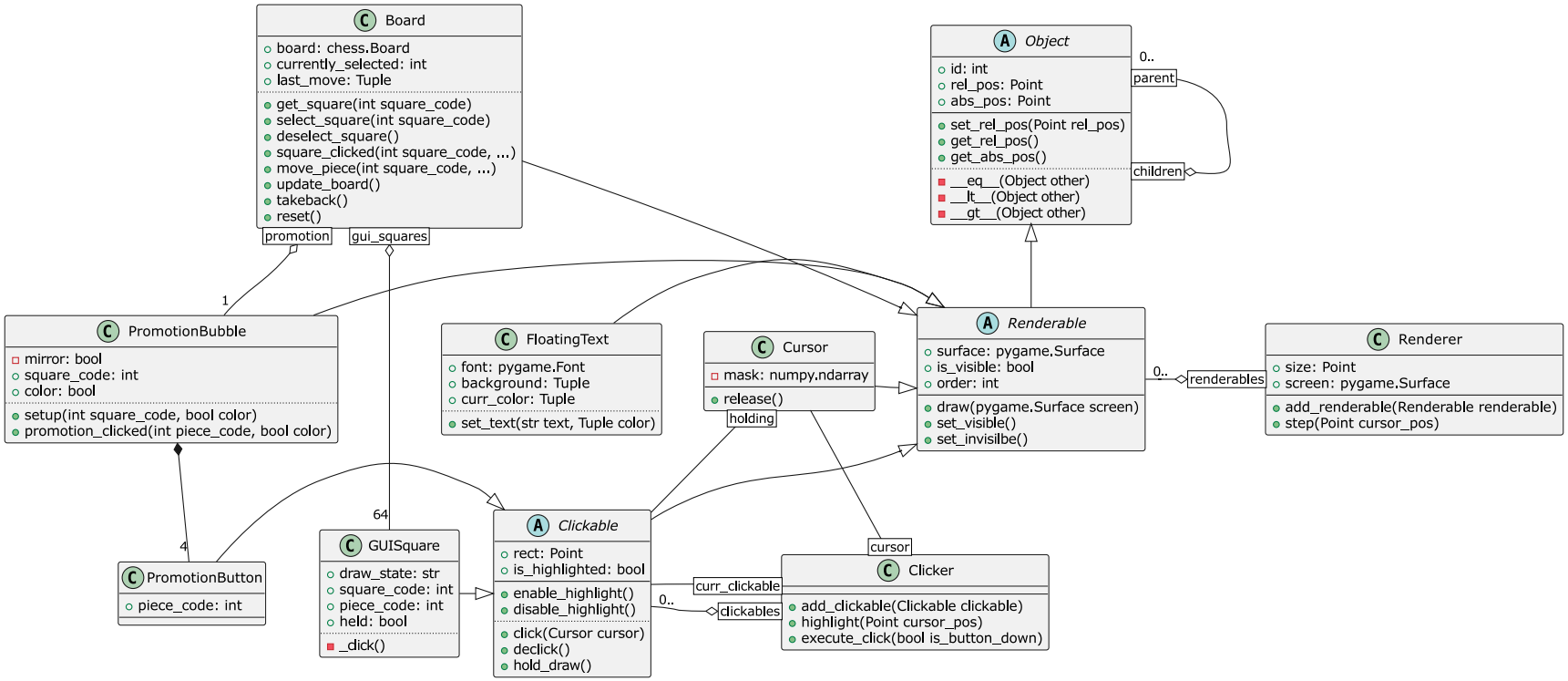


Figure: Class diagram of the game's elements

A bit in detail 1

The `Renderer`...draws `Renderables`!

1. Keeps track of them.
2. Draws them based on each object's `order` attribute.
3. Draws them only if they are set to visible.

The `Clicker`:

1. Keeps track of the `Clickables`.
2. Highlights the current `Clickable`, calls its click/declick method.
3. Drives hold/release with `Cursor`.

A bit in detail 2

Our `Cursor` is this neat thing:

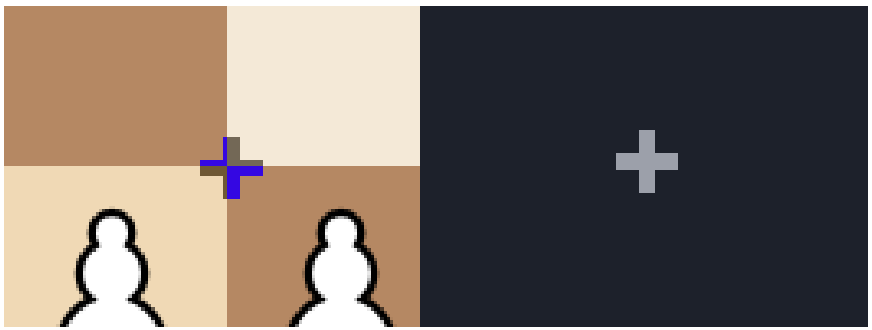


Figure: Our `Cursor`.

It is simple, but we are pretty happy about it:

1. It is extremely visible, because of the dynamic color

$$c^* = (c + 128) \bmod 256.$$

2. It can hold pieces.
3. Being stylistically different might have helped!

A bit in detail 3

The `Board`:

1. Wraps a `chess.Board` object (and all its complicated chess logic).
2. Handles the state of all the `GUISquare` and that of the `PromotionBubble`.
3. Plays audio when moves are done!

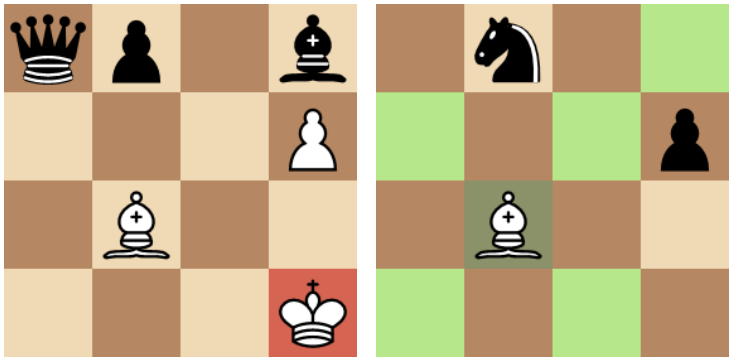


Figure: Examples of `GUISquare` states

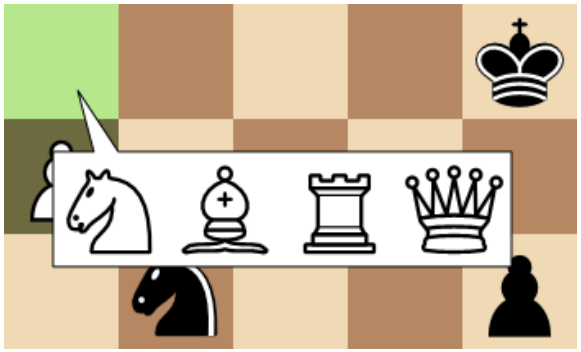


Figure: What `PromotionBubble` looks like

The main loop

All of this runs on the main thread, within the loop:

1. Update cursor with latest mouse or hand position.
2. `clicker.highlight(cursor_pos)`.
3. Resolve events, such as mouse clicks, key presses (quit game, takebacks), and moves done (for the AI).
4. Resolve voice commands.
5. `renderer.step()`.
6. Run metrics recorder.

Dragonfly? What's that?

We have to get from here...

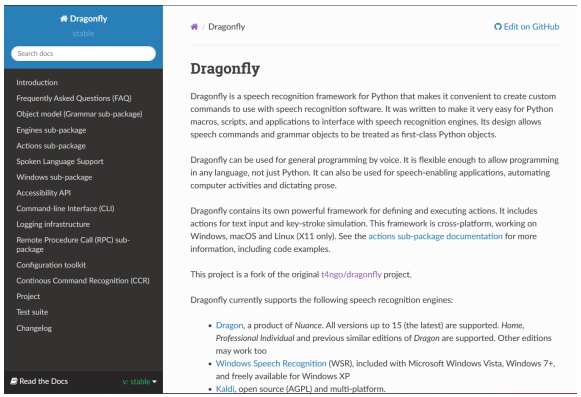


Figure: What we have.

To here!

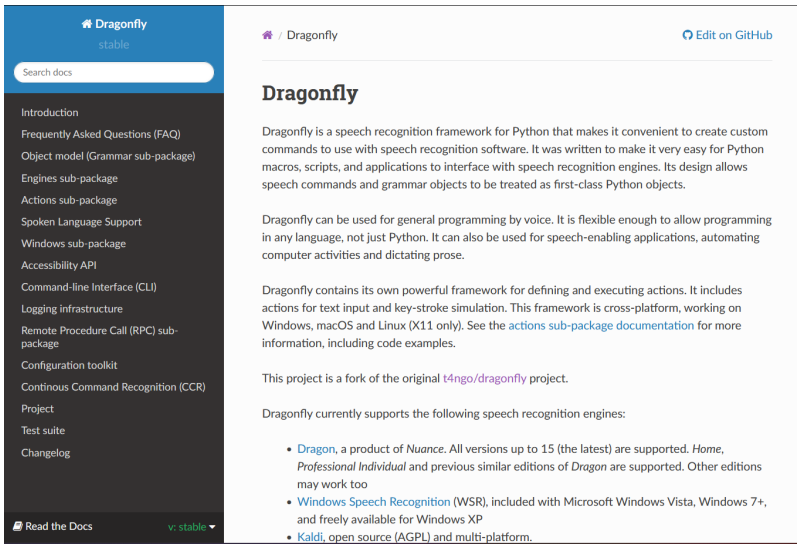


Figure: What we want.

Hey, but what is a Rule?

Rules 1

Table: Rules Pt.1

Rule Name	**Specification**
Move Rule	"move ([<src_piece>] | [<src_piece> [<prep> <src_square>] to <tgt_square>] | [[<prep>] <src_square> to <tgt_square>]) [and promote to <prm_piece>]"
Capture Rule	"capture (<tgt_piece> [<prep> <tgt_square>] | <tgt_square>) [with (<src_piece> [<prep> <src_square>] | <src_square>)] [and promote to <prm_piece>]"
Promote Rule	"promote [(<src_piece> | <src_square>)] to <prm_piece>"

Rules 2

Table: Rules Pt.1

Rule Name	**Specification**
Castle Rule	"(castle <special_direction> | <special_direction> castle)"
Piece Rule	"<src_piece> ([<prep>] <tgt_square> |in <src_square> <verb> [<prep>] (<tgt_square> | <tgt_piece> [in <tgt_square>]) | <verb> [<prep> <src_square>]([<prep>] <tgt_square> | <tgt_piece> [in <tgt_square>])) [and promote to <prm_piece>]"
Square Rule	"<src_square> <verb> ([<prep>] <tgt_square> | <tgt_piece> [<prep> <tgt_square>])"

Validating commands

Good ol' mediapipe

Of course, we use `mediapipe` for hand tracking.

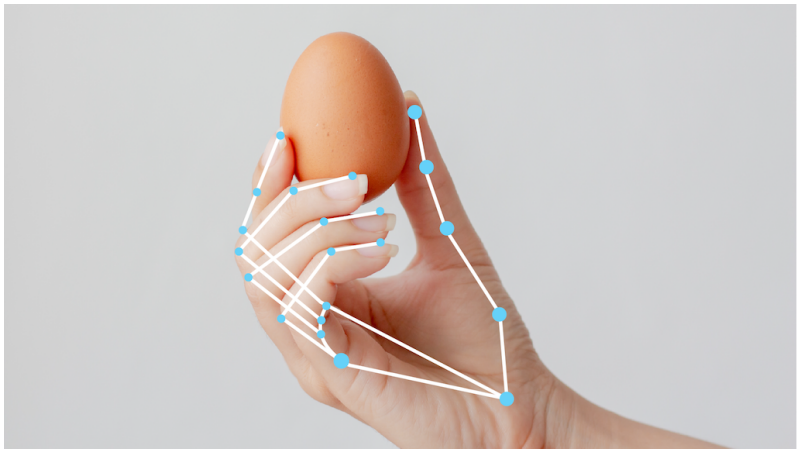


Figure: You know what this is.

1. We run it on a separate thread (`HandDetector`).
2. Process it for our needs.
3. Make it temporally coherent.

'Hand'made normalization 1

Get palm center:

$$p = \frac{\mathbf{L}_1}{2} + \frac{\mathbf{L}_6 + \mathbf{L}_{10} + \mathbf{L}_{14} + \mathbf{L}_{18}}{8}. \tag{1}$$

Its width

$$w = ||\mathbf{L}_6 - \mathbf{L}_{18}||_2, \tag{2}$$

and compute the relative position:

$$\bar{\mathbf{L}} = \frac{\mathbf{L} - p}{w}. \tag{3}$$

'Hand'made normalization 2

Find the palm's normal:

$$\mathbf{n}_{\text{palm}} = (1 - \mathbf{2}_{\text{left}}) \frac{(\mathbf{L}_6 - \mathbf{L}_1) \times (\mathbf{L}_{18} - \mathbf{L}_1)}{||(\mathbf{L}_6 - \mathbf{L}_1) \times (\mathbf{L}_{18} - \mathbf{L}_1)||_2}. \tag{4}$$

Then we get the pinky normal,

$$\mathbf{n}_{\text{pinky}} = (1 - \mathbf{2}_{\text{left}}) \frac{\mathbf{n}_{\text{palm}} \times (\mathbf{L}_{10} - \mathbf{L}_1)}{||\mathbf{n}_{\text{palm}} \times (\mathbf{L}_{10} - \mathbf{L}_1)||_2}. \tag{5}$$

And the fingers' normal,

$$\mathbf{n}_{\text{fingers}} = (1 - \mathbf{2}_{\text{left}}) \frac{\mathbf{n}_{\text{pinky}} \times \mathbf{n}_{\text{palm}}}{||\mathbf{n}_{\text{pinky}} \times \mathbf{n}_{\text{palm}}||_2}. \tag{6}$$

'Hand'made normalization 3

Finally,

$$\mathbf{L}^{\star} = \overline{\mathbf{L}}\left[\mathbf{n}_{\text{pinky}}, \mathbf{n}_{\text{fingers}}, \mathbf{n}_{\text{palm}}\right]^{T} \tag{7}$$

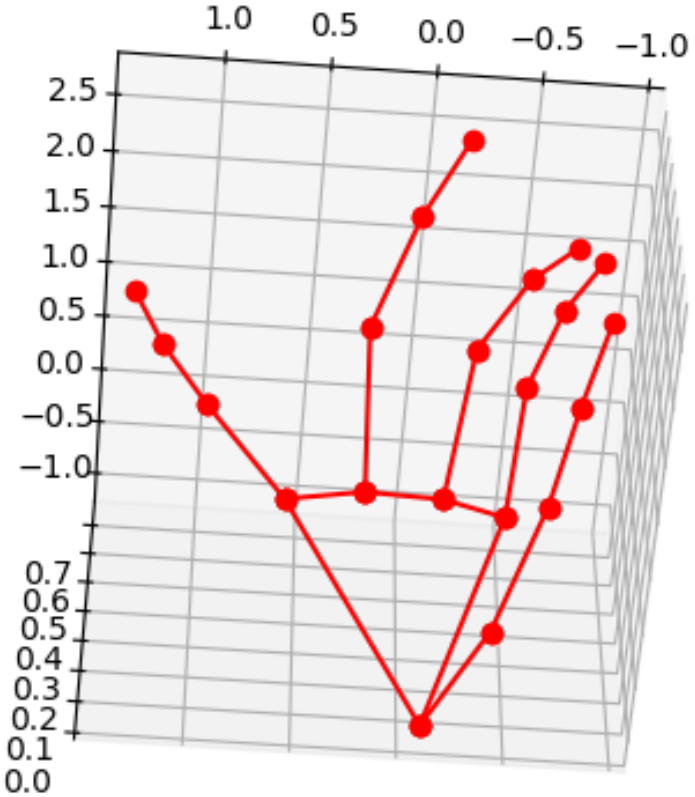


Figure: A right hand, normalized

Gesture recognition

At first, we wanted two gestures:

1. Tapping gesture, for "clicks". ☹
2. Grabbing gesture, to hold pieces. ☺

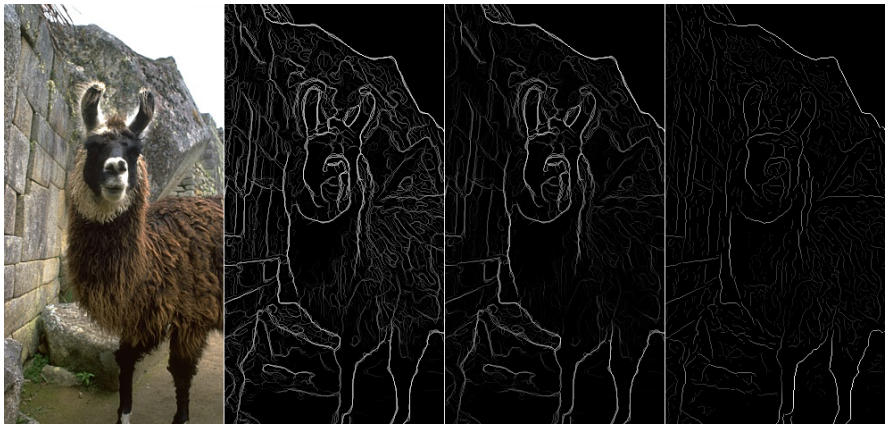
Figure: Frame from "A Guided Tour of Apple Vision Pro"

Recognizing grab

Very simple: hysteresis.

1: **input** `prev_click`
2: $m \leftarrow ||\mathbf{L}^{\star}_{\text{thumb}} - \mathbf{L}^{\star}_{\text{index}}||_2$
3: $d \leftarrow \frac{\mathbf{L}^{\star}_{\text{thumb}} \cdot \mathbf{L}^{\star}_{\text{index}}}{||\mathbf{L}^{\star}_{\text{thumb}}||_2 ||\mathbf{L}^{\star}_{\text{index}}||_2}$
4: **if** `prev_click` **then**
5: **return** $m < \alpha_\gamma \wedge d > \beta_\gamma$
6: **else**
7: **return** $m < \alpha \wedge d > \beta$
8: **end if**

Remember the Canny edge detector?



That uses hysteresis too!

Hand2Cursor mapping

The direct mapping is

$$r = \text{clip}_{[m,M]}(\frac{p-m}{M-m}). \quad (8)$$

But we can't directly use r...
Let c be the internal cursor of `HandDetector`.

1. Noisy tracking: c moves at constant rate, either bilinear or linear interpolation, if r_{t-1} present.
2. Cursor moving when hand still: only update if distance is enough.
3. Random dropping of pieces: keep a list of most recent detections, if even one is a grab then output a grab.

Recording users

Some metrics

Results 1

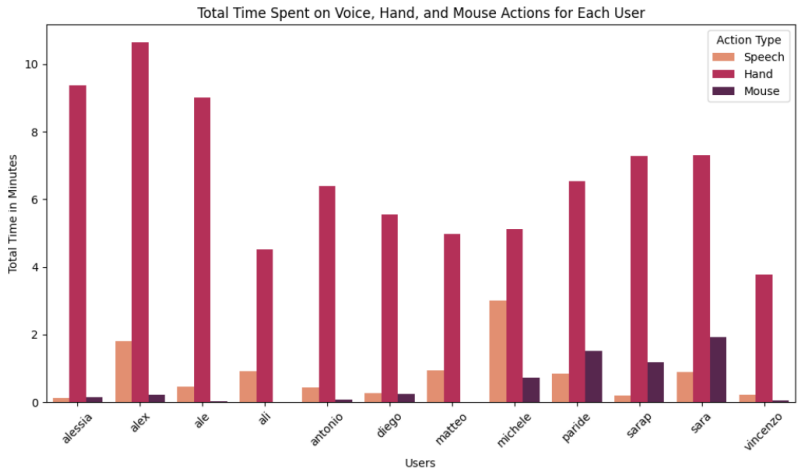


Figure: **Total Time** (seconds) on Voice, Hand and Mouse Actions per user

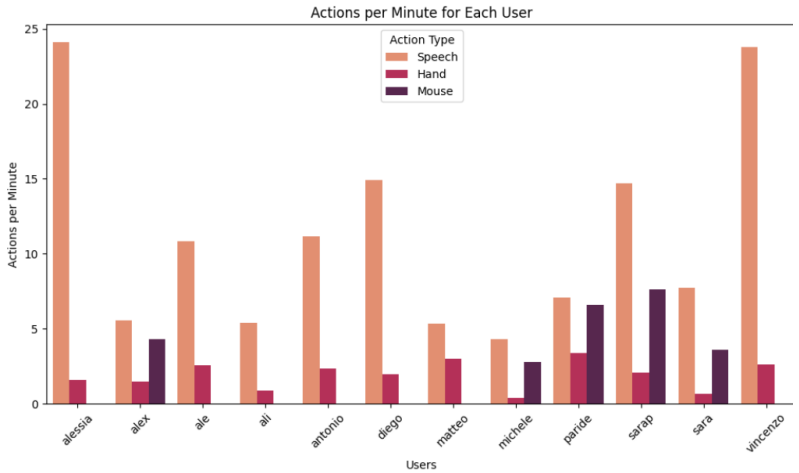


Figure: **Actions per Minute** per user

Results 2

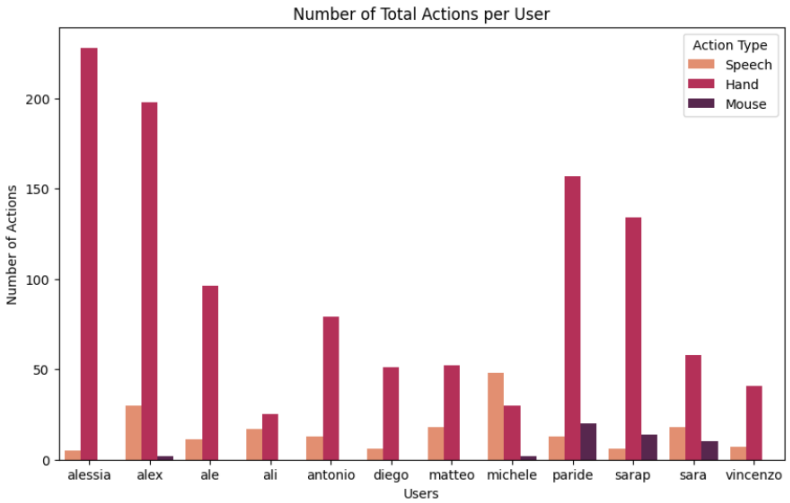


Figure: Number of **Total** Actions per user

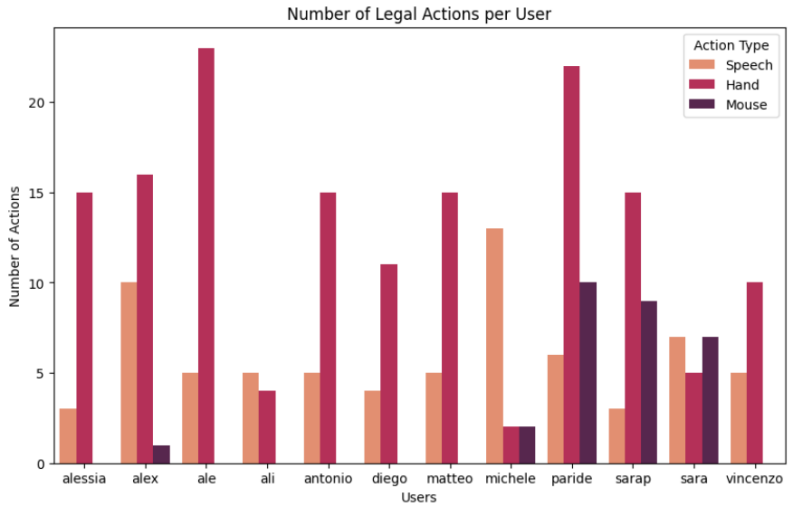


Figure: Number of **Legal** Actions per user

Results 3

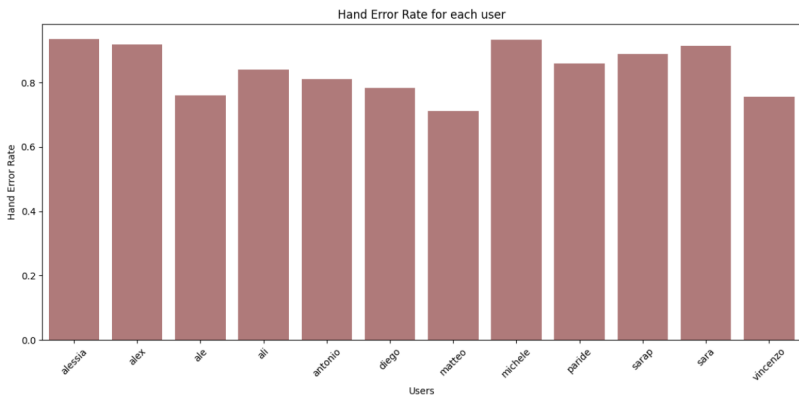


Figure: **Error rate** for **Hand** actions

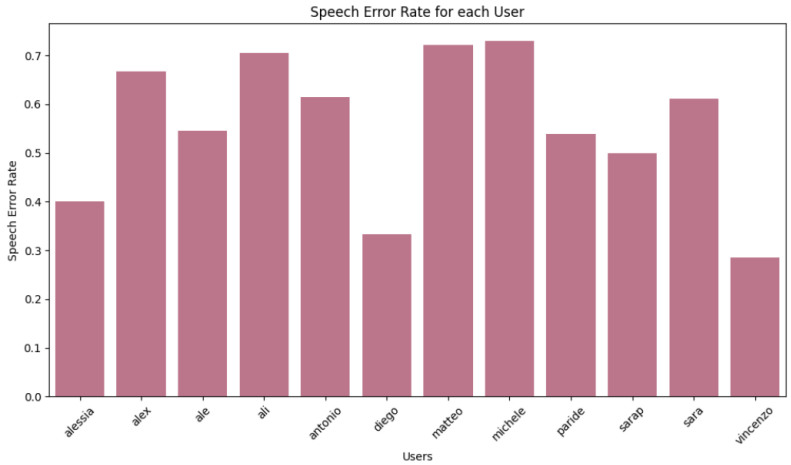


Figure: **Error rate** for **Voice** actions

Conclusions