

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...

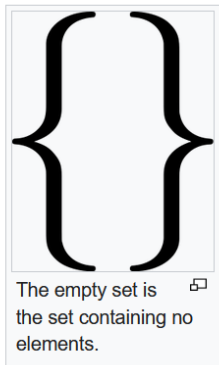


Figure: What we have.

To here!

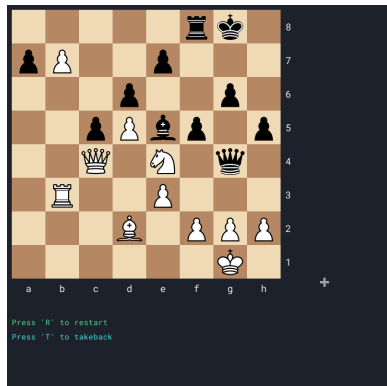


Figure: What we want.

We need some OOP

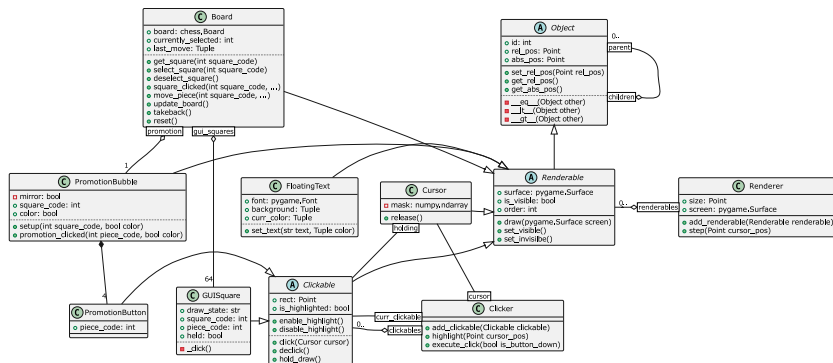


Figure: Class diagram of the game's elements

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!

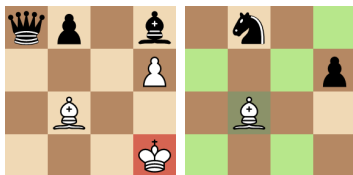


Figure: Examples of `GUISquare` states



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?

Not this. . .



Figure: The insect.

This!

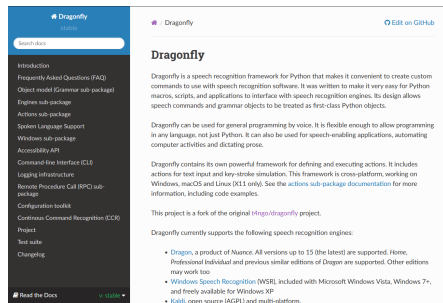


Figure: The package.

Hey, but what is a Rule?

```
class PromoteRule(CompoundRule):  
  
    def __init__(self, manager):  
        super().__init__()   
        self.manager = manager  
  
    spec = "promote [<src_piece> | <src_square>]] to <prm_piece>"  
    extras = [  
        Choice("prep", prep_map),  
        Choice("src_piece", piece),  
        Choice("prm_piece", prm_piece),  
        Compound( name = "src_square", spec = "<file> <rank>", extras = [ Choice("file", file_map), Choice("rank", rank_map)],  
                  value_func = lambda node, extras: (extras["file"], extras["rank"]))  
    ]
```

Figure: Example of Compound Rule

Each rule is instantiated as a Compound Rule, with parameters :

- spec : Compound specification for the rules root element
- extras : Extras elements referenced from the compound spec, like choices for prepositions, pieces, and squares.

Hey, but what is a Rule? - ALTERNATIVE

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It is characterized by a process recognition method that bla bla bla

Rules I

Table: Rules I

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 II

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.

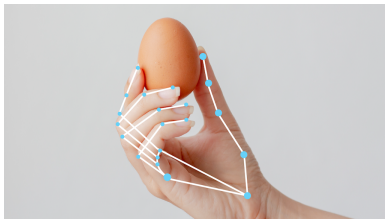


Figure: You know what this is.

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:

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

Its width

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

and compute the relative position:

$$\bar{\mathbf{L}} = \frac{\mathbf{L} - p}{w}. \quad (3)$$

'Hand'made normalization 2

Find the palm's normal:

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

Then we get the pinky normal,

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

And the fingers' normal,

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

'Hand'made normalization 3

Finally,

$$\mathbf{L}^* = \bar{\mathbf{L}} [\mathbf{n}_{\text{pinky}}, \mathbf{n}_{\text{fingers}}, \mathbf{n}_{\text{palm}}]^T \quad (7)$$

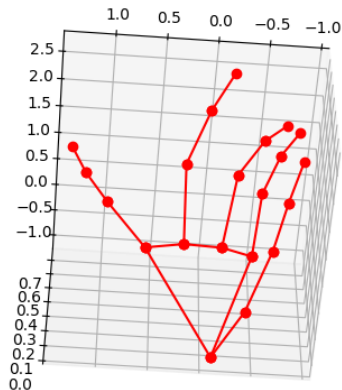


Figure: A right hand, normalized

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:  $m \leftarrow ||\mathbf{L}_{\text{thumb}}^* - \mathbf{L}_{\text{index}}^*||_2$   
3:  $d \leftarrow \frac{\mathbf{L}_{\text{thumb}}^* \cdot \mathbf{L}_{\text{index}}^*}{||\mathbf{L}_{\text{thumb}}^*||_2 ||\mathbf{L}_{\text{index}}^*||_2}$   
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

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

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 System I

```
1  {
2    "fen": "r2qk2r/ppp1bppp/2n1bn2/3pp3/4P3/3P1P2/PPP2KPP/RNB1QBNR",
3    "player": [
4      {
5        "action_start": "2024-05-28 20:14:37.066157", "action_end": "2024-05-28 20:14:42.439008",
6        "action_type": "mouse", "action_dist": 811.0, "down_button": 0, "up_button": 0,
7        "moves": []
8      },
9      {
10       "action_start": "2024-05-28 20:14:42.439008", "action_end": "2024-05-28 20:15:06.577269",
11       "action_type": "hand", "action_dist": 539.4, "down_button": 3, "up_button": 3,
12       "moves": []
13     },
14     {
15       "action_start": "2024-05-28 20:15:06.577269", "action_end": "2024-05-28 20:15:31.592501",
16       "action_type": "speech", "utterances": 7,
17       "moves": [["pawn", "a2", "a3", null]]
18     }
19   ],
20   "ai": [["pawn", "e7", "e5", null]]
21 }
```

Each recording is organized into two primary sections, namely **Player Actions** and **AI Moves**.

Recording System II

Each action performed contains information about :

- Type : Mouse, Hand or Voice
- Start & End Time : Time of Action Start and End
- Moves : (Source Piece, Source Square, Target Piece, Target Square, Promotion Piece)
- Optional : Utterances, Hand & Mouse Distance, Hand & Mouse Bottoms Up and Down

Results, Total Time

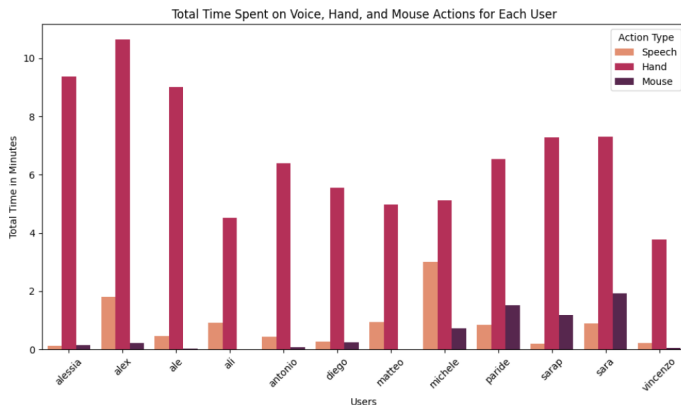


Figure: Total Time (seconds) on Voice, Hand and Mouse Actions per user

Results, APM

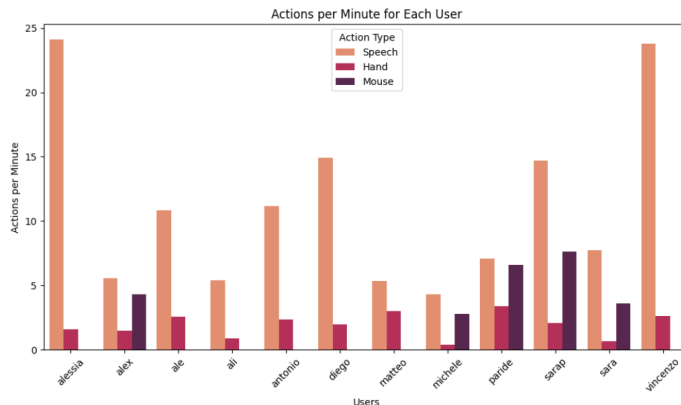


Figure: Actions per Minute per user

Results, Total Actions

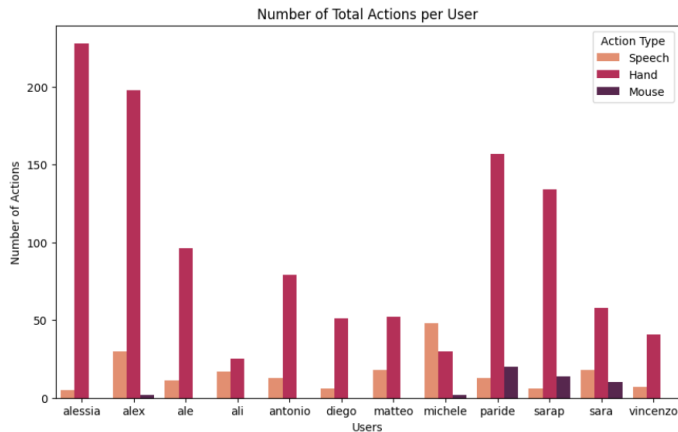


Figure: Number of **Total** Actions per user

Results, Legal Actions

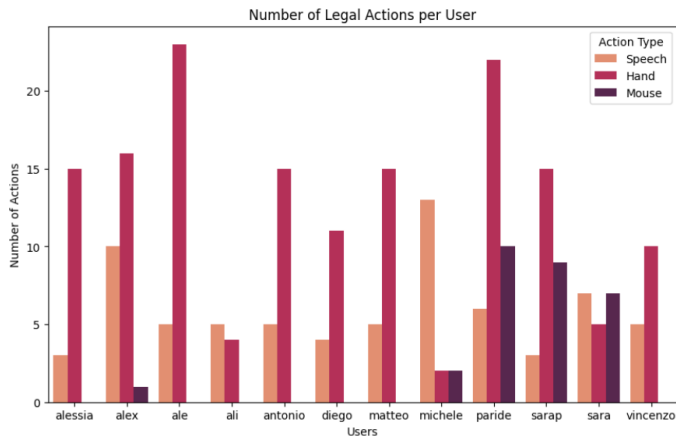


Figure: Number of **Legal** Actions per user

Results, Error rate hand

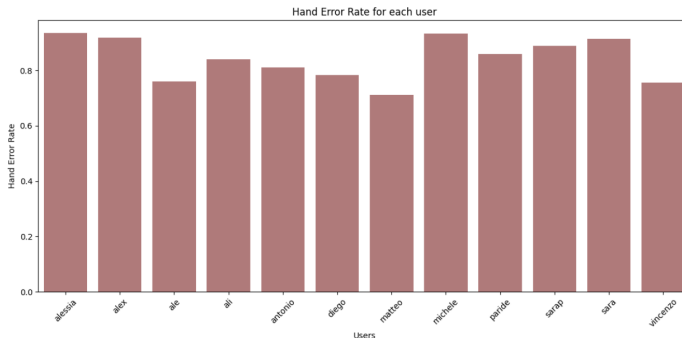


Figure: Error rate for Hand actions

Results, Error rate voice

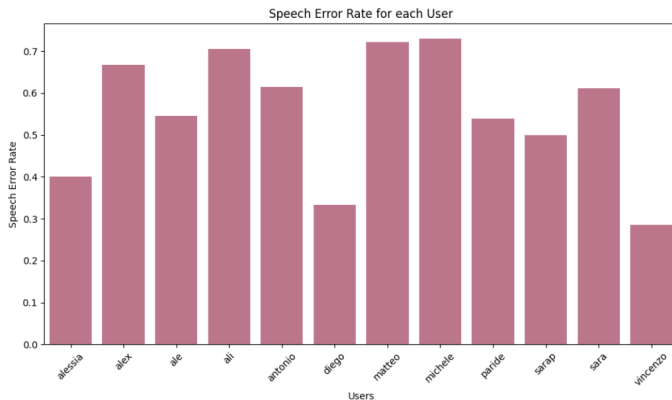


Figure: **Error rate** for **Voice** actions

Conclusions

Something something



Figure: Fin.