



DEPARTAMENTO
DE COMPUTACION

Facultad de Ciencias Exactas y Naturales - UBA

Análisis de feature sets con redes neuronales NNUE para engines de ajedrez

May 22, 2024

Martín Emiliano Lombardo
mlombardo9@gmail.com

Directores

Agustín Sansone
agustinsansone7@gmail.com

Diego Fernández Slezak
dfslezak@dc.uba.ar



Facultad de Ciencias Exactas y Naturales

Universidad de Buenos Aires

Ciudad Universitaria - (Pabellón Cero + Infinito)

Intendente Güiraldes 2610 - C1428EGA

Ciudad Autónoma de Buenos Aires - Rep. Argentina

Tel/Conmutador: (+54 11) 5285-9721 / 5285-7400

<https://dc.uba.ar>

Contents

1	Introduction	2
1.1	Chess Engines	2
2	Feature sets (board encodings)	3
2.1	Indexing	4
2.2	PIECE	4
2.3	COMPACT	4
2.4	PIECE+MOVES	4
2.5	HALF-KING-PIECE	4
2.6	HALF-RELATIVE(H V HV)KING-PIECE	5
2.7	HALF-TOP(PP)	5
2.8	Recap	5
3	Efficiently updatable neural networks	6
3.1	Architecture	6
3.2	Efficient updates	6
3.3	Stockfish quantization scheme	6
3.4	Network sparsity	7
4	Training	8
4.1	Dataset	8
4.2	Methods	8
4.2.1	Stockfish evaluations	8
4.2.2	PQR triplets	8
4.3	Metrics	8
5	Engine implementation	9
5.1	Alpha-Beta	9
5.2	Prunes	9
6	Results	10
6.1	Active neurons	10
7	Final words	11
7.1	Conclusions	11
7.2	Future work	11

1 Introduction

1.1 Chess Engines

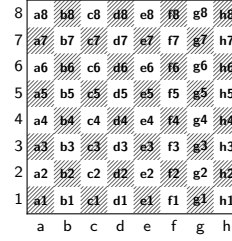
2 Feature sets (board encodings)

To evaluate chess positions, we will use a neural network with an architecture explained in detail in the next chapter. In this chapter, we will build the one-dimensional input vector for such network, which can be described entirely by a feature set.

A feature set is a set built by a cartesian product of smaller sets of features, where each set extracts a different aspect of a position. Each tuple in the feature set corresponds to an element in the input vector, which will be set to 1 if the aspects captured by the tuple is present in the position, and 0 otherwise. If a tuple is present in a position, we say that the tuple is *active*.

Let's consider some basic sets of features. The following sets encode positional information about the board:

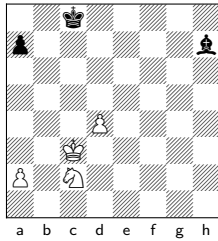
$$\begin{aligned}\text{FILE} &= \{a, b, \dots, h\} \\ \text{RANK} &= \{1, 2, \dots, 8\} \\ \text{SQUARE} &= \{a1, a2, \dots, h8\}\end{aligned}$$



And the following encode information about the pieces:

$$\begin{aligned}\text{ROLE} &= \{ \text{♙ Pawn}, \text{♘ Knight}, \text{♗ Bishop}, \text{♖ Rook}, \text{♕ Queen}, \text{♔ King} \}^1 \\ \text{COLOR} &= \{ \text{○ White}, \text{● Black} \}\end{aligned}$$

Since each set has to capture some information from the position, it must be stated explicitly. For example, consider the feature set $\text{FILE}_P \times \text{COLOR}_P$ where P is *any* piece in the board, meaning that the tuples $(file, color)$ that will be active are the ones where there is at least one piece in $file$ with the color $color$ (disregarding any other kind of information, like the piece's role). Another possible feature set could be $\text{FILE}_P \times \text{ROLE}_P$, with a similar interpretation. An illustration of the active features of these two feature sets for the same position is shown in Figure 2.



	Feature set	
	$\text{FILE}_P \times \text{COLOR}_P$	$\text{FILE}_P \times \text{ROLE}_P$
Active features	$(a, \text{○}), (a, \text{●}), (c, \text{●}), (c, \text{○}), (d, \text{○}), (h, \text{●})$	$(a, \text{♙}), (c, \text{♕}), (c, \text{♗}), (d, \text{♙}), (h, \text{♙})$

Figure 1: Active features of the feature sets $\text{FILE}_P \times \text{COLOR}_P$ and $\text{FILE}_P \times \text{ROLE}_P$ for the same position

¹The color of the pieces have no meaning in the definition. They are present for illustrative purposes.

2.1 Indexing

The mapping between the tuples in a feature set and the elements in the input vector is computed using the order of the sets in the cartesian product and the size of each set, like strides in a multi-dimensional array. For this to work, each element in a set S must correspond to a number between 0 and $|S| - 1$. For example, the feature set $A \times B \times C$ has $|A| \times |B| \times |C|$ elements, and the tuple (a, b, c) is mapped to the element $a \times |B| \times |C| + b \times |C| + c$.

2.2 PIECE

This feature set is the most natural encoding for a chess position. There is a one-to-one mapping between pieces in the board and features:

$$\text{PIECE} = \text{SQUARE}_p \times \text{ROLE}_p \times \text{COLOR}_p$$

for every p piece in the board

$$\langle \text{piece_square}, \text{piece_type}, \text{piece_color} \rangle$$

$$64 * 6 * 2 = 768 \text{ features}$$

2.3 COMPACT

This is one of the simplest feature sets.

$$\langle \text{piece_rank}, \text{piece_type}, \text{piece_color} \rangle \oplus \langle \text{piece_file}, \text{piece_type}, \text{piece_color} \rangle$$

$$(8 * 6 * 2) * 2 = 192 \text{ features}$$

2.4 PIECE+MOVES

$$\text{HALFP} \oplus \langle \text{move_from}, \text{move_to} \rangle$$

$$768 + 64 * 64 = 4864 \text{ features}$$

Not friendly to efficiently update the network. It is almost always better to do a full refresh on eval.

2.5 HALF-KING-PIECE

$\text{KING-PIECE} = \text{SQUARE}_K \times \text{PIECE}_P$ where K is the king to move and P is any *non-king* piece

$$\langle \text{side_king_square}, \text{piece_square}, \text{piece_type}, \text{piece_color} \rangle \text{ excl. king}$$

$$64 * 64 * 5 * 2 = 40960 \text{ features}$$

There are variations to this feature set, such as `HALFKAV2` or notably `HALFKAV2_HM` that is currently the latest feature set used by Stockfish 16.1. I will not consider them in this work.

known as "KP" in the literature

if we skip the king, you may be thinking where does it get the information about the other king's side, blabla arquitectura Half

2.6 HALF-RELATIVE(H|V|HV)KING-PIECE

$\langle side_king_file - piece_file + 7, side_king_rank - piece_rank + 7, piece_type, piece_color \rangle$
 excl. king

$15 * 15 * 5 * 2 = 2250$ features (for HV)

only H or only V have $8 * 15 * 5 * 2 = 1200$ features

2.7 HALF-TOP(PP)

Statistical feature set, blabla, wasted features blabla

2.8 Recap

Feature set	Tuple	# features
PIECE	$SQUARE_P \times ROLE_P \times COLOR_P$	768
COMPACT	asd	192
PIECE+MOVES	asd	4864
KING-PIECE	asd	40,960
RELATIVEHV-KING-PIECE	asd	2250
TOPPP	asd	64

Table 1: Comparison of feature sets

3 Efficiently updatable neural networks

NNUE (Efficiently updatable neural network) is a neural network architecture that allows for very fast inferences. It was invented for Shogi by Yu Nasu in 2018.

In essence, NNUEs "Neural Network Update Efficient" are just regular neural networks that allow for really fast inferences.

... Most of the information described here can be found in Stockfish's documentation about NNUEs [1].

It is important to combine this with aggressive quantization techniques.

3.1 Architecture

arquitectura half, dos capas

3.2 Efficient updates

pesada al principio y liviana al final, acumular filas de la primera capa en domove, undo-move

3.3 Stockfish quantization scheme

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. If you read this text, you will get no information $E = mc^2$. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. There is no need for special content, but the length of words should match the language. $a\sqrt[n]{b} = \sqrt[n]{a^n b}$. Hello, here is some text without a meaning. $d\Omega = \sin\vartheta d\vartheta d\varphi$. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sin^2(\alpha) + \cos^2(\beta) = 1$. This text should contain all letters of the alphabet and it should be written in of the original language $E = mc^2$. There is no need for special content, but the length of words should match the language. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. Hello, here is some text without a meaning. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. This text should show what a printed text will look like at this place. $a\sqrt[n]{b} = \sqrt[n]{a^n b}$. If you read this text, you will get no information. $d\Omega = \sin\vartheta d\vartheta d\varphi$. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression

of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language. $\sin^2(\alpha) + \cos^2(\beta) = 1$. Hello, here is some text without a meaning $E = mc^2$. This text should show what a printed text will look like at this place. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. If you read this text, you will get no information. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $a \sqrt[n]{b} = \sqrt[n]{a^n b}$. This text should contain all letters of the alphabet and it should be written in of the original language. $d\Omega = \sin\vartheta d\vartheta d\varphi$. There is no need for special content, but the length of words should match the language. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. If you read this text, you will get no information $E = mc^2$. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. There is no need for special content, but the length of words should match the language. $a \sqrt[n]{b} = \sqrt[n]{a^n b}$.

This is text bla bla. ²

More testing on section 3.3.

Rango de activación: en el modelo original usamos ClippedReLU, así que queremos que el rango vaya de 0..1 a 0..127.

Siendo \mathbf{x} , \mathbf{w} y \mathbf{b} los parámetros de una capa lineal sin cuantizar e \mathbf{y} la salida de la misma, se tiene que:

$$\begin{aligned} \mathbf{y} &= \mathbf{x}\mathbf{w} + \mathbf{b} \\ s_a s_w \mathbf{y} &= (s_a \mathbf{x})(s_w \mathbf{w}) + s_a s_w \mathbf{b} \end{aligned} \tag{1}$$

$$s_o((s_a \mathbf{x})(s_w \mathbf{w}) + s_a s_w \mathbf{b}) = s_a s_w s_o \mathbf{y}$$

3.4 Network sparsity

o combinar con 3.2? poner graficos con la sparsity de cada feature set, decir que es muy esparso todo y que se podría mejorar aún más

²This is a example footnote

4 Training

4.1 Dataset

Lichess is a free online site to play chess, and it provides a database¹ with all the games played on the site. It consists of several compressed PGN files² splitted by month since 2013, that add up to 1.7 terabytes compressed. It contains over 5 billion games, that equates to around 200 billion positions. In reality, that many positions are too much to handle so I'll use only a fraction of them, but I restrict derived datasets to only take one sample per game, to maximize the diversity of positions.

decir que la data de entrenamiento no es la misma. SF original usaba datos de hand-crafted, hoy en dia usa de LC0. Nosotros usamos de Lichess, computada por el SF moderno

4.2 Methods

4.2.1 Stockfish evaluations

4.2.2 PQR triplets

This is an additional technique I wanted to try, described in [METER REF BLOG]. Remember that we are trying to obtain a function f (the model) to give an evaluation of a position. The method is based in the assumption that players make optimal or near-optimal moves most of the time, even if they are amateurs.

1. For two position in succession $p \rightarrow q$ observed in the game, we will have $f(p) \neq f(q)$.
2. Going from p , not to q , but to a *random* position $p \rightarrow r$, we must have $f(r) > f(q)$ because the random move is better for the next player and worse for the player that made the move.

... With infinite compute, f would be the result of running minimax to the end of the game, since minimax always finds optimal moves.

4.3 Metrics

asd [1]

¹Lichess database: <https://database.lichess.org>

²Portable Game Notation: a textual format to store chess games (moves and metadata)

5 Engine implementation

5.1 Alpha-Beta

5.2 Prunes

6 Results

6.1 Active neurons

medir si hay feature sets que no usen neuronas, que esto disparo el uso de HalfTopK

7 Final words

7.1 Conclusions

7.2 Future work

References

- [1] Yu Nasu. “NNUE: Efficiently Updatable Neural-Network-based Evaluation Functions for Computer Shogi”. In: *Ziosoft Computer Shogi Club* (2018). URL: https://www.apply.computer-shogi.org/wcsc28/appeal/the_end_of_genesis_T.N.K.evolution_turbo_type_D/nnue.pdf.