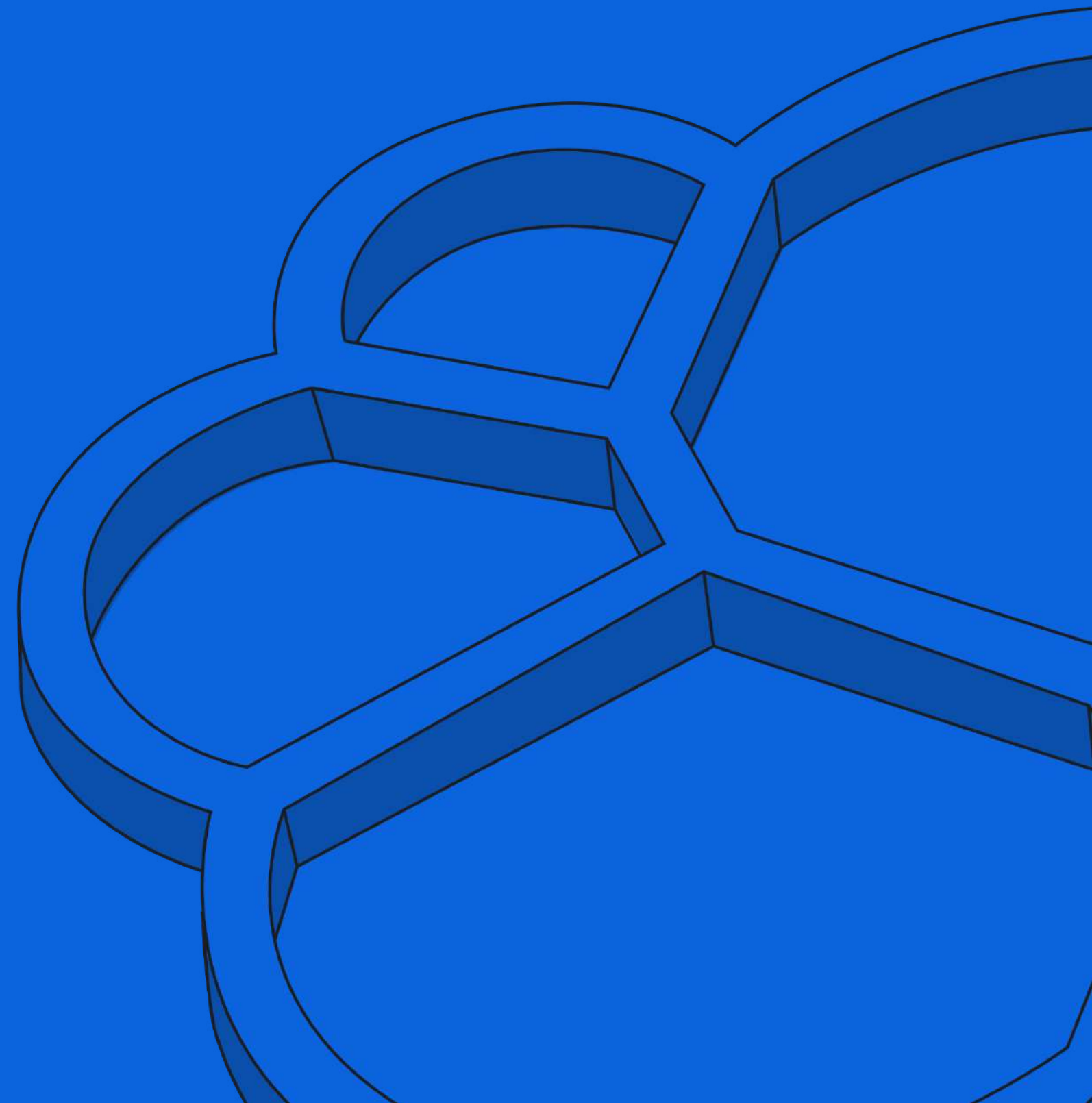


13 Levels of Search

June 2026



Jon Avezbaki

- **Software Engineer, worked on**
 - trading chatbots
 - banking mobile apps
 - autonomous vehicle systems
 - & more
- **Developer Advocate**
- **Full-Time Tech Enthusiast**



Agenda (1/3) — Beginner

01

Linear Search

02

Binary Search

03

Hash Tables

Agenda (2/3) — Intermediate

04	Inverted Index
05	TF
06	IDF
07	BM25
08	Text Analysis

Agenda (3/3) — Advanced

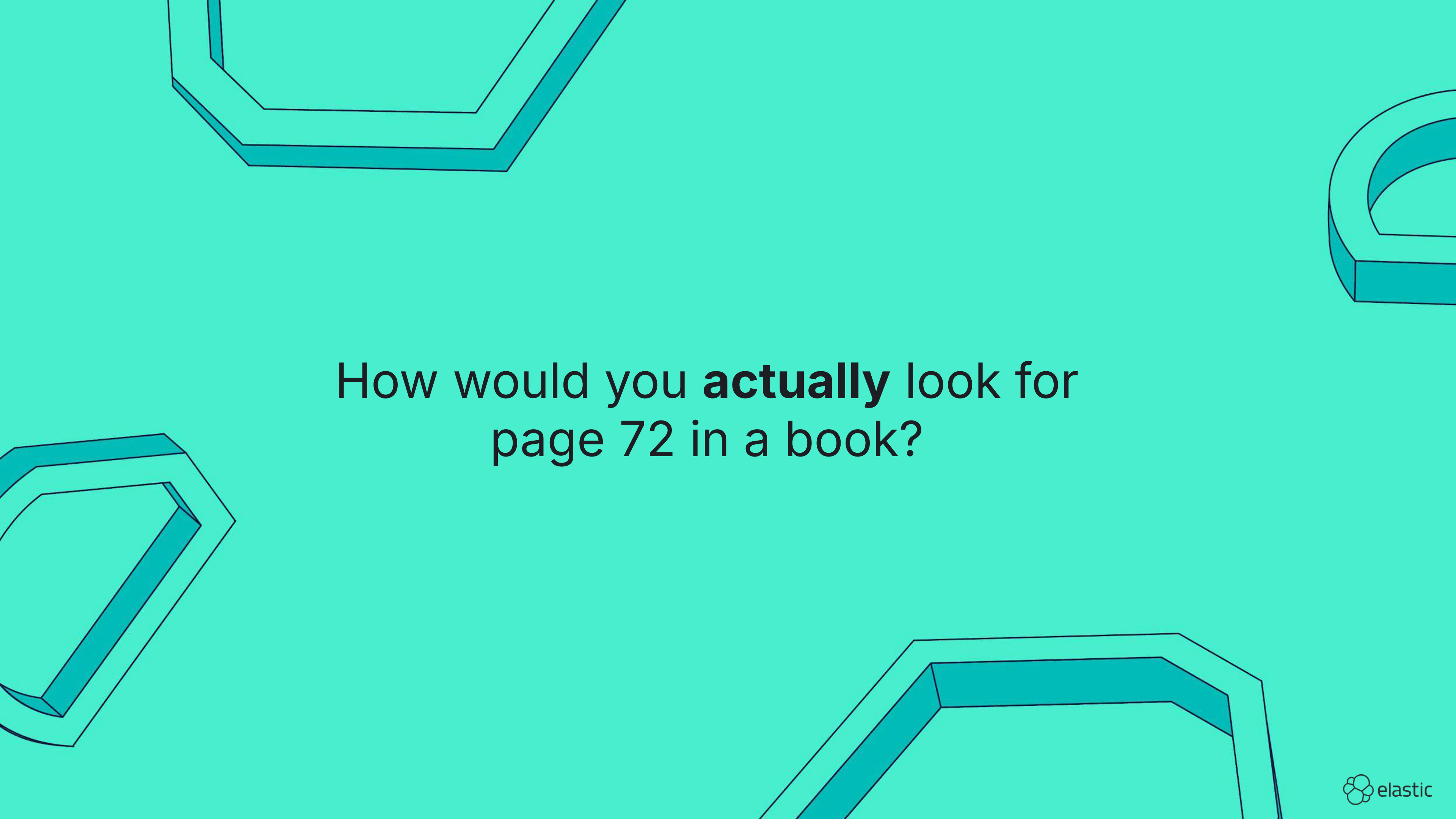
09	Rerankers
10	Vectors
11	Hybrid Search
12	RAG
13	Agentic Memory

Level 1: Linear Search

Ok class, let's open our books to
page 72.

- ❌ Brute Force
- ❌ Slow — $O(n)$
- ❌ Doesn't leverage the fact that every book is ordered by page number

Level 2: Binary Search

The background features several abstract, teal-colored geometric shapes. In the top left, there is a complex, multi-layered shape resembling a stylized 'L' or a corner. In the top right, a curved, shell-like shape is visible. On the left side, there is a shape that looks like a stylized 'C' or a partial circle. In the bottom right, there is a large, angular shape with multiple facets. The overall aesthetic is modern and minimalist.

How would you **actually** look for
page 72 in a book?

Level 3: Hash Tables

What page does Chapter 2 start on?

INTRODUCTION
6

KEY INGREDIENTS
8

PIZZA ESSENTIALS
8

INDEX
156

BASICS

12

NEAPOLITAN

26

NEW CLASSICS

68

DEEP PAN

90

FRIED and STUFFED

112

SWEET

126

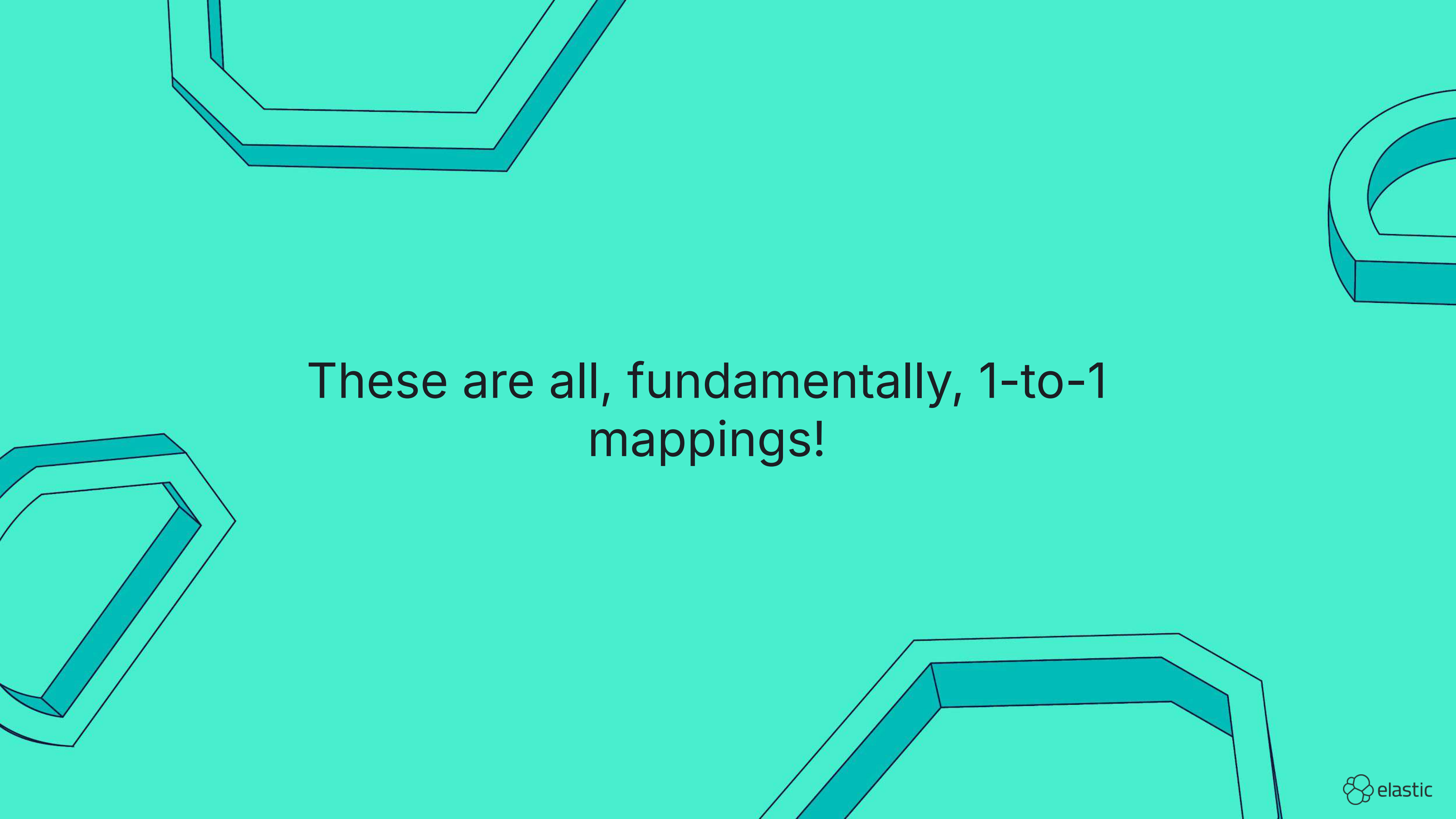
KEY	VALUE
Chapter 2	Page 26

KEY	VALUE
Chapter 2	Page 26
98	

KEY	VALUE
Chapter 2	Page 26
98	
License plate #	

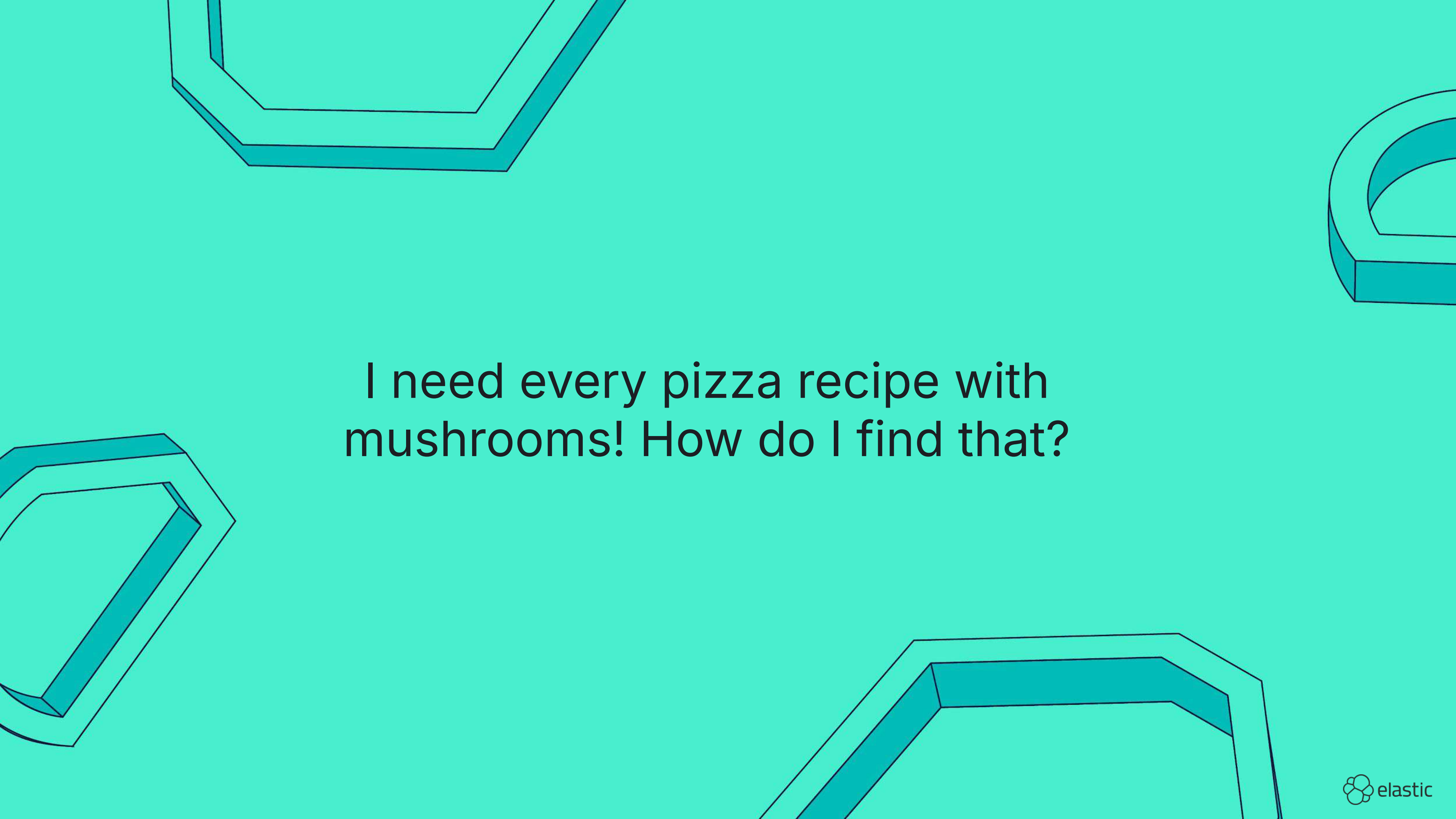
KEY	VALUE
Chapter 2	Page 26
98	
License plate #	
Social Security Number #	

KEY	VALUE
Chapter 2	Page 26
98	
License plate #	
Social Security Number #	
Credit Card Number #	

The background features four decorative teal geometric shapes in the corners: a stepped L-shape in the top-left, a curved shape in the top-right, a hexagonal shape in the bottom-left, and a stepped L-shape in the bottom-right.

These are all, fundamentally, 1-to-1 mappings!

Level 4: Inverted Indices



I need every pizza recipe with
mushrooms! How do I find that?

137 **EXERCISES**

y lamb 80

leek, gorgonzola & v

kale pesto 25

hini yoghurt

n, thym

52

non &

Spicy Mexican sweetcorn with
smoked mozzarella 86

The Hawaiian 72

Wagyu bresaola 74

mushrooms

Capricciosa 34

Mushroom, thyme, rosemary &
fontina 52

mussels: Smoked mussel 63

N

P

pancetta

Amatriciana

parmesan

Basil pesto

Chicago

Chicago

'Nduja

Pepper

Prosciutto

Ricotta

Spicy

smoked

dough 14

Level 5: TF

TF

TF

Term Frequency

TF

Term Frequency

How often a term shows up in a document

The background features several abstract, 3D-style geometric shapes in a teal color. These shapes are composed of multiple parallel lines, creating a sense of depth and movement. They are positioned in the corners and along the edges of the slide, framing the central text.

I run a search for:
"tasty artichoke pizza recipe"

How will the TF algorithm score
different recipes for this query?

Recipe A

The Most Perfect Vanilla Birthday Cake Recipe

Last Saturday my best friend Jenna turned 35, and she asked me — ME! — to make her birthday cake. I was so honored. We've been friends since college and I still remember the first time I baked for her (brownies, totally dry, she ate three anyway).

The party was at her place in Bushwick. Her husband Mark handled the savory side — he ordered these incredible artichoke pizzas from the spot on DeKalb Ave. You know the kind, thin crust, marinated artichoke hearts, garlic, a little lemon zest. Honestly when the food showed up I almost forgot I was there to present a cake.

Anyway, I knew Jenna wanted something classic. Not fussy, not fondant, just a really good vanilla cake with buttercream. I tested three recipes the week before. The first recipe was too dense. The second recipe tasted like a candle. The third — the recipe I'm sharing here — was perfect. I knew I'd found the right recipe when Jenna's mom asked for it before the party even started.

The day of the party, I showed up with the cake. Everything was so tasty that night. Jenna said it was the best birthday — and that this tasty cake recipe was a keeper.



Ingredients:

- 2¾ cups all-purpose flour
- 2 cups granulated sugar
- 1 tbsp baking powder
- 1 tsp salt
- 1 cup unsalted butter, softened
- 4 large eggs
- 1 cup whole milk
- 2 tsp vanilla extract

Buttercream:

- 1½ cups unsalted butter, softened
- 5 cups powdered sugar
- 3 tbsp heavy cream
- 2 tsp vanilla extract
- Pinch of salt

Instructions:

1. Preheat oven to 350°F. Grease and flour two 9-inch round pans.
2. Whisk flour, sugar, baking powder, and salt together.
3. Add butter and mix on medium until crumbly. Add eggs one at a time, then milk and vanilla. Beat until smooth, about 2 minutes.
4. Divide between pans. Bake 28–32 minutes until a toothpick comes out clean.
5. Cool completely before frosting.
6. For buttercream: beat butter until fluffy, add powdered sugar gradually, then cream, vanilla, and salt. Beat on high 3–4 minutes.
7. Frost between layers, then top and sides.

Recipe B

No-Fluff Artichoke Pizza Recipe

Ingredients:

- 1 lb pizza dough (or make your own — I use a 72-hour ferment)
- ¾ cup marinated artichoke hearts, drained and quartered
- 1½ cups shredded low-moisture mozzarella
- 2 cloves garlic, thinly sliced
- 2 tbsp good olive oil
- Zest of half a lemon
- Red pepper flakes, to taste
- Flaky salt

Instructions:

1. Preheat oven to 500°F (or as hot as it goes) with a baking steel or stone on the middle rack for at least 45 minutes.
2. Stretch dough thin to about 12 inches. Transfer to a floured peel or sheet of parchment.
3. Brush the surface with olive oil. Scatter mozzarella evenly, then distribute artichoke hearts and garlic slices.
4. Slide onto the steel/stone. Bake 8–10 minutes until the crust is charred in spots and the cheese is bubbling and just starting to brown.
5. Pull it out, hit it immediately with lemon zest, red pepper flakes, and flaky salt.



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Recipe B

No-Fluff Artichoke Pizza Recipe

Ingredients:

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Recipe A

TERM	FREQUENCY (TF SCORE)
tasty	2
artichoke	2
pizza	1
recipe	7

Recipe B

TERM	FREQUENCY (TF SCORE)
tasty	0
artichoke	3
pizza	2
recipe	0

Recipe A (12)

The Most Perfect Vanilla Birthday Cake Recipe

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5. Cool completely before frosting.
6. For buttercream: beat butter until fluffy, add powdered sugar gradually, then cream, vanilla, and salt. Beat on high 3–4 minutes.
7. Frost between layers, then top and sides.

Recipe B

No-Fluff Artichoke Pizza Recipe

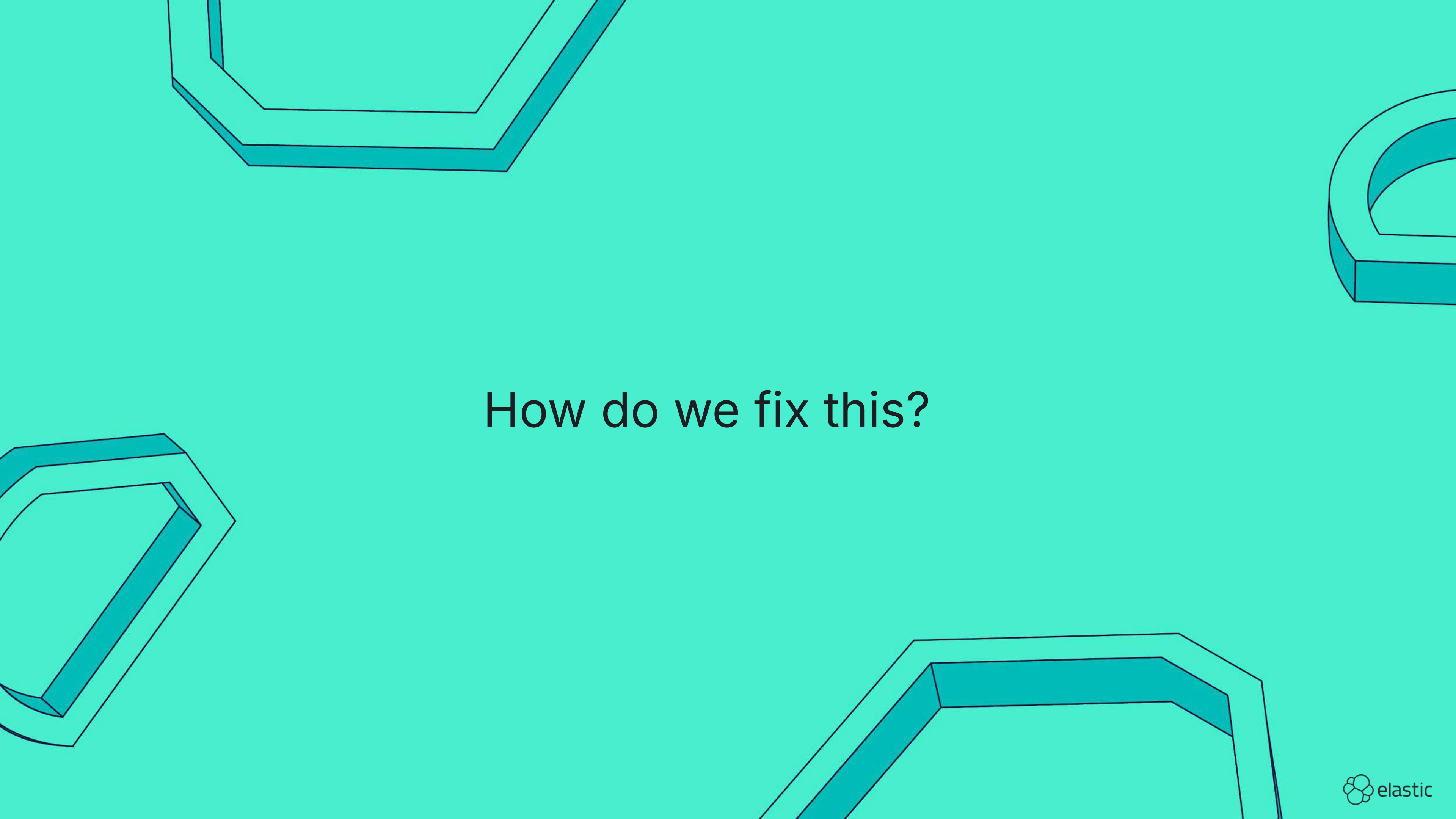
Ingredients:

- 1 lb pizza dough (or make your own — I use a 72-hour ferment)
- ¾ cup marinated artichoke hearts, drained and quartered
- 1½ cups shredded low-moisture mozzarella
- 2 cloves garlic, thinly sliced
- 2 tbsp good olive oil
- Zest of half a lemon
- Red pepper flakes, to taste
- Flaky salt

Instructions:

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How do we fix this?

Level 6: IDF

IDF

IDF

Inverse Document Frequency

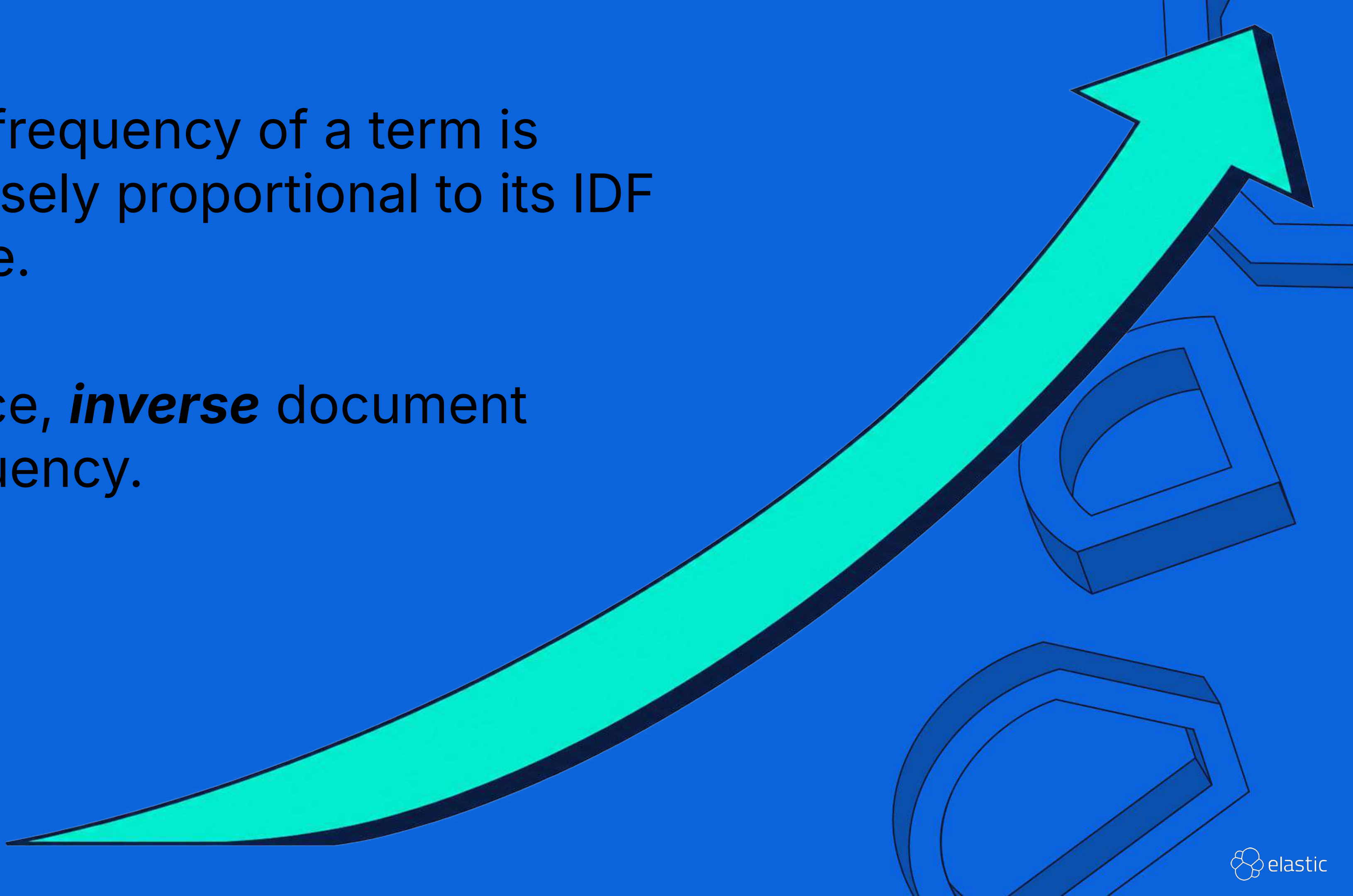
IDF

Inverse Document Frequency

How rare a term is in our database

The frequency of a term is
inversely proportional to its IDF
score.

Hence, *inverse* document
frequency.



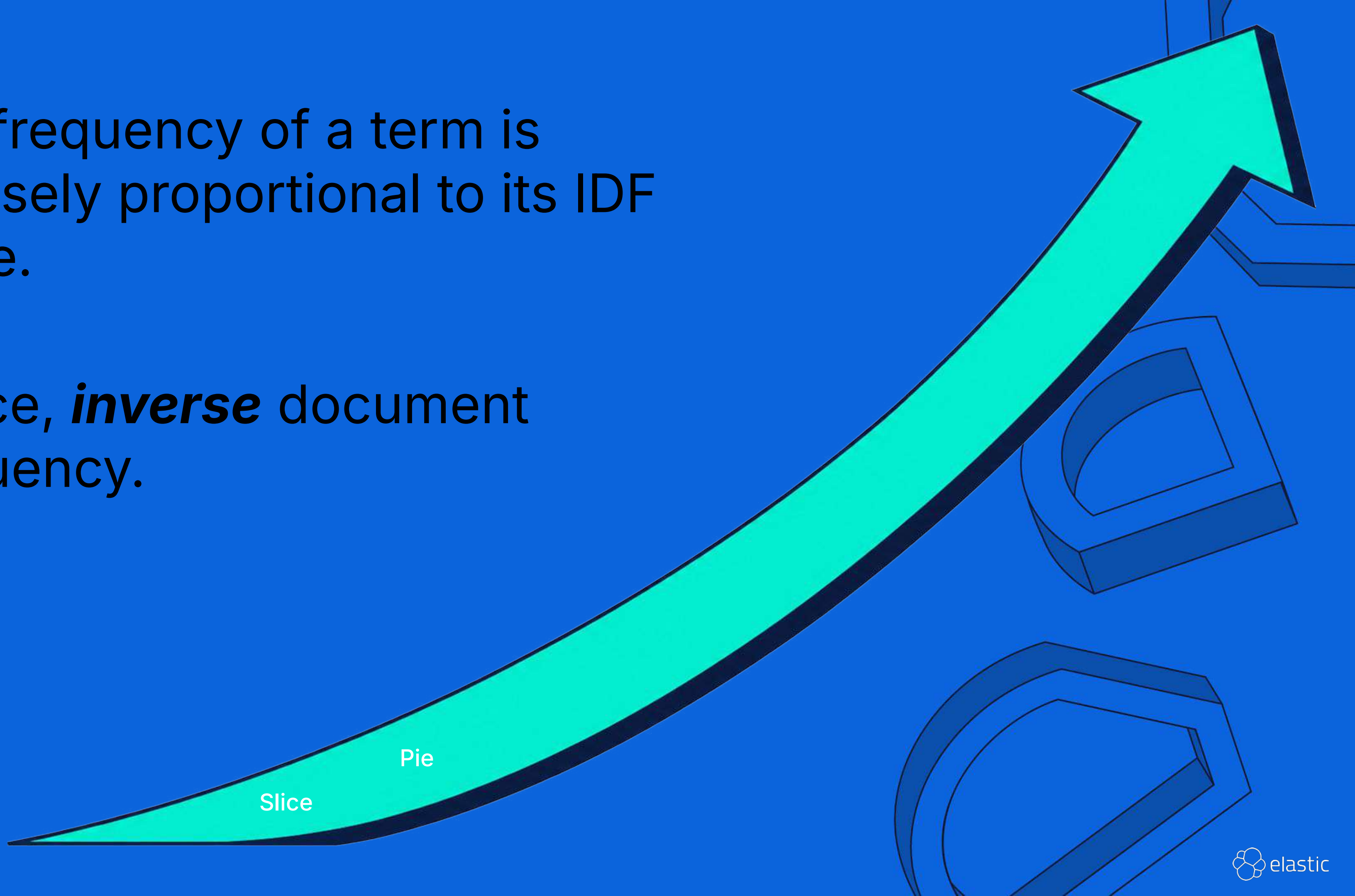
The frequency of a term is
inversely proportional to its IDF
score.

Hence, *inverse* document
frequency.

Slice

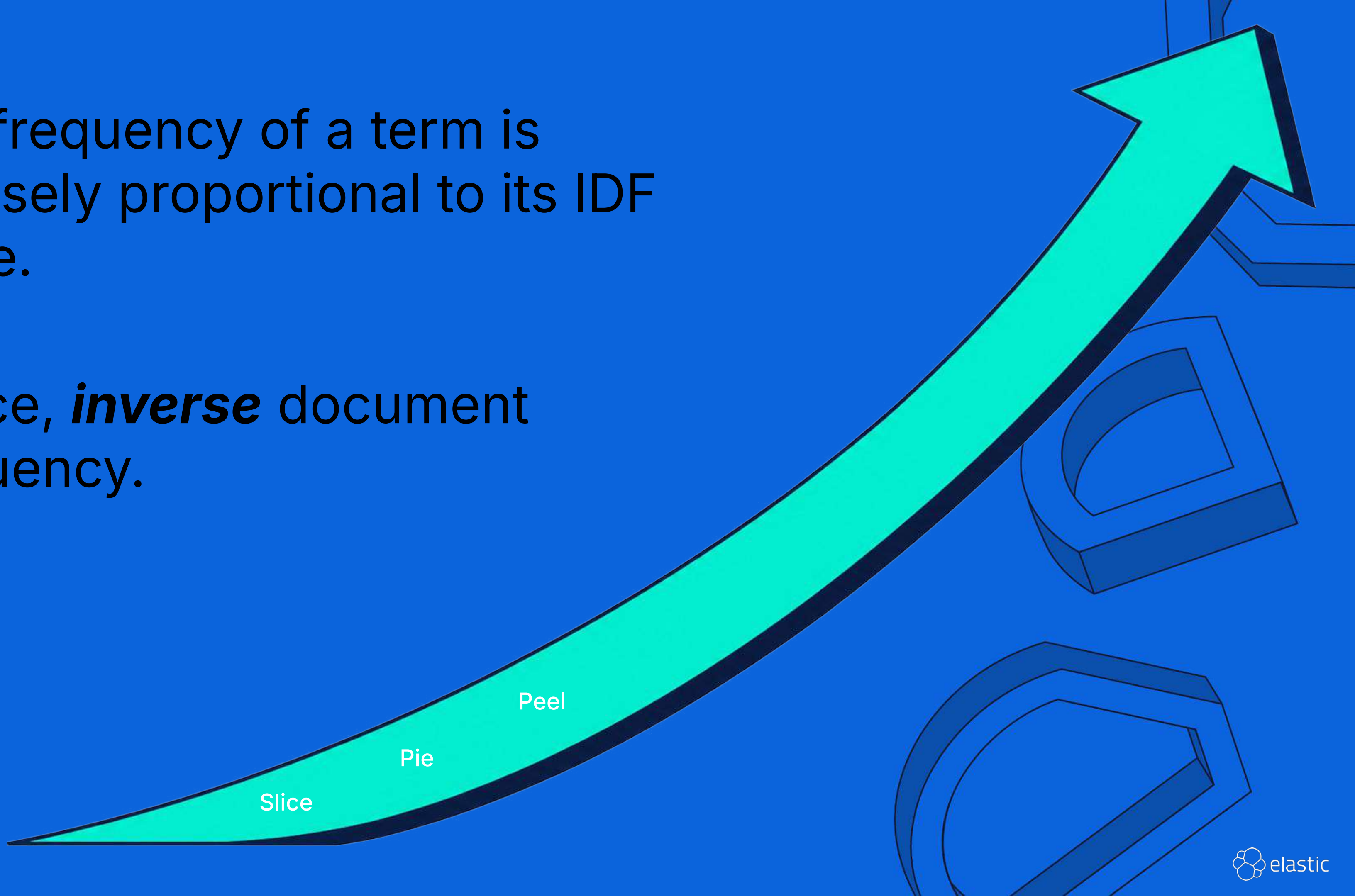
The frequency of a term is
inversely proportional to its IDF
score.

Hence, *inverse* document
frequency.



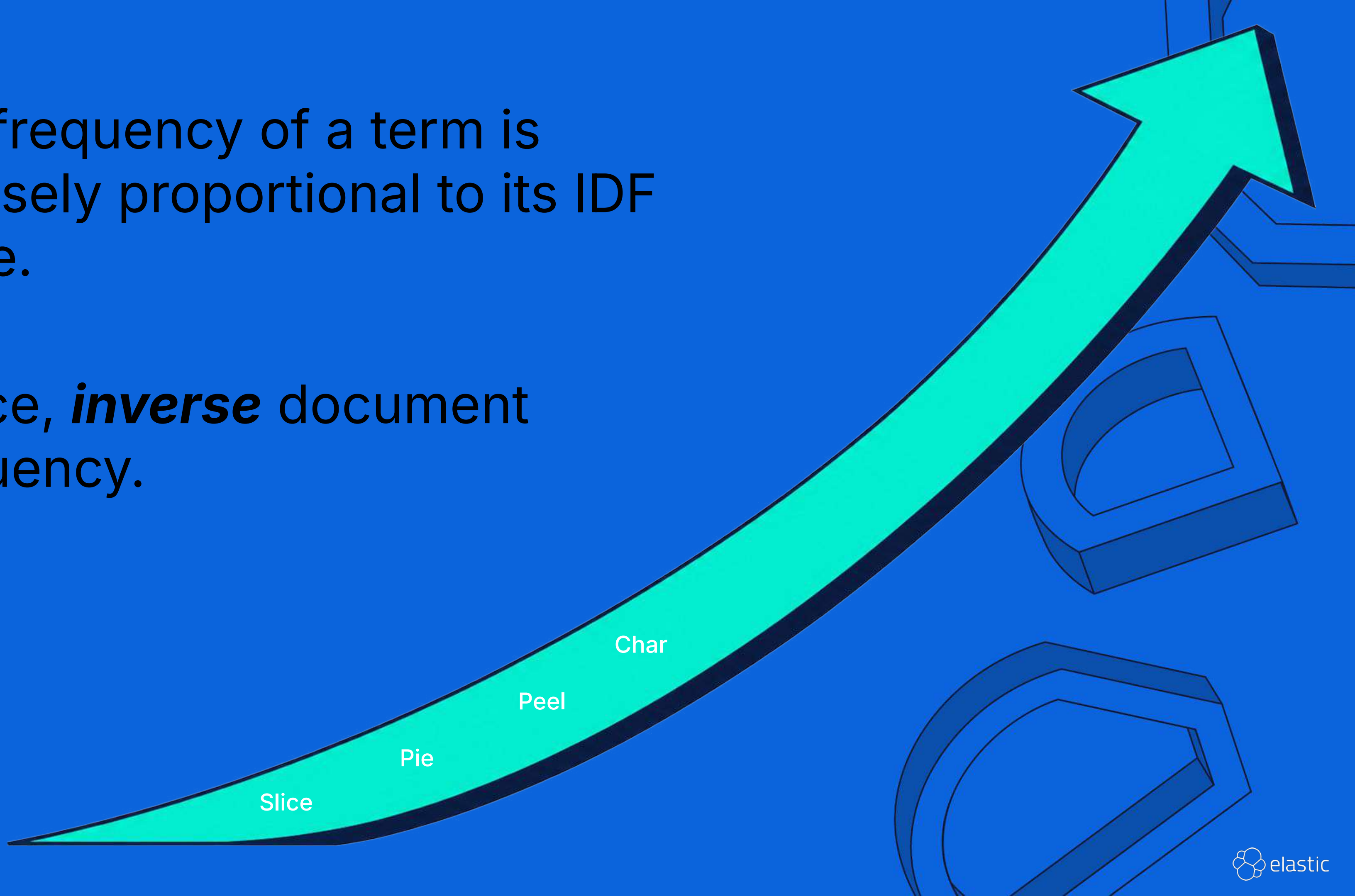
The frequency of a term is
inversely proportional to its IDF
score.

Hence, *inverse* document
frequency.



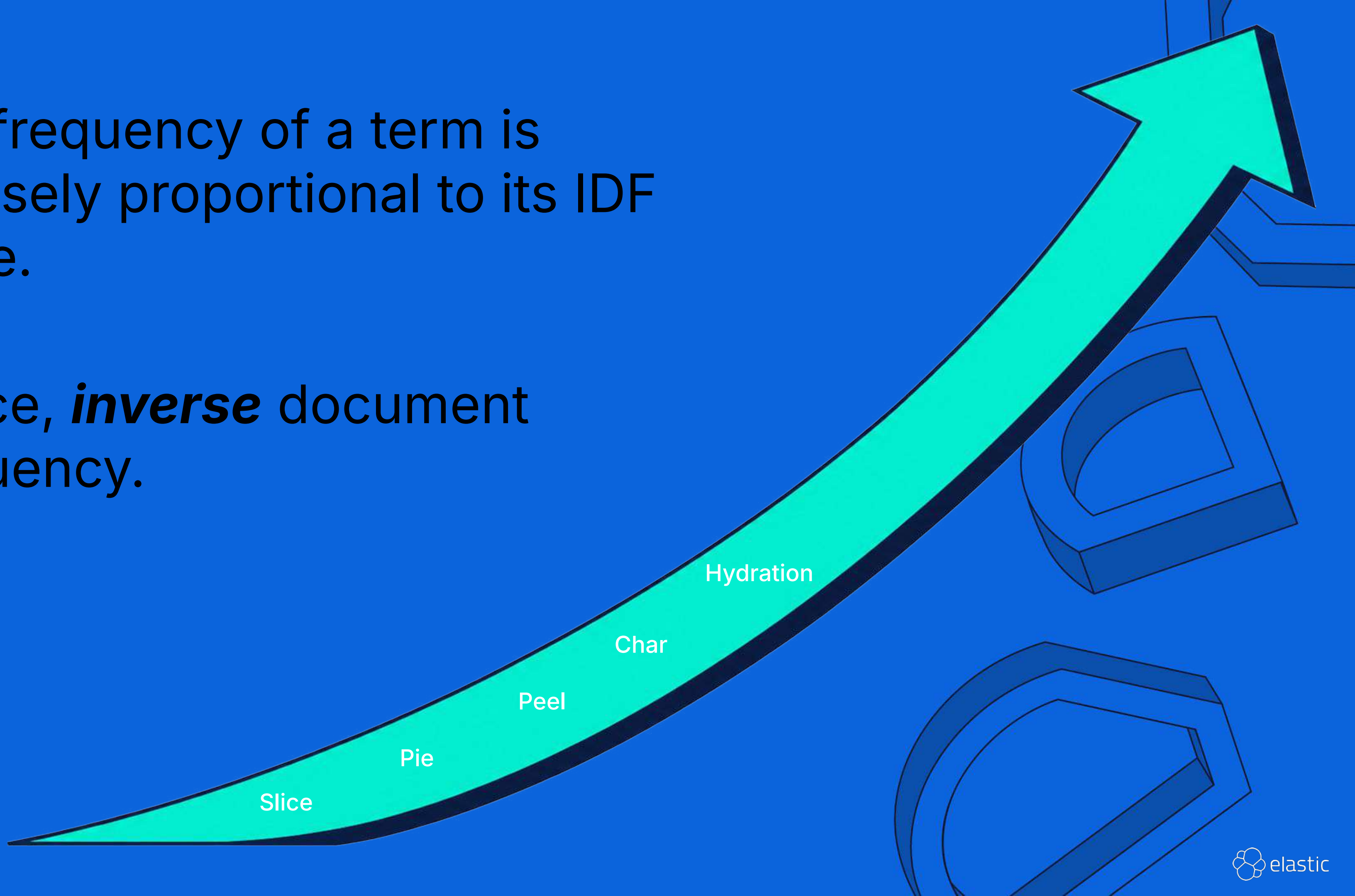
The frequency of a term is
inversely proportional to its IDF
score.

Hence, ***inverse*** document
frequency.



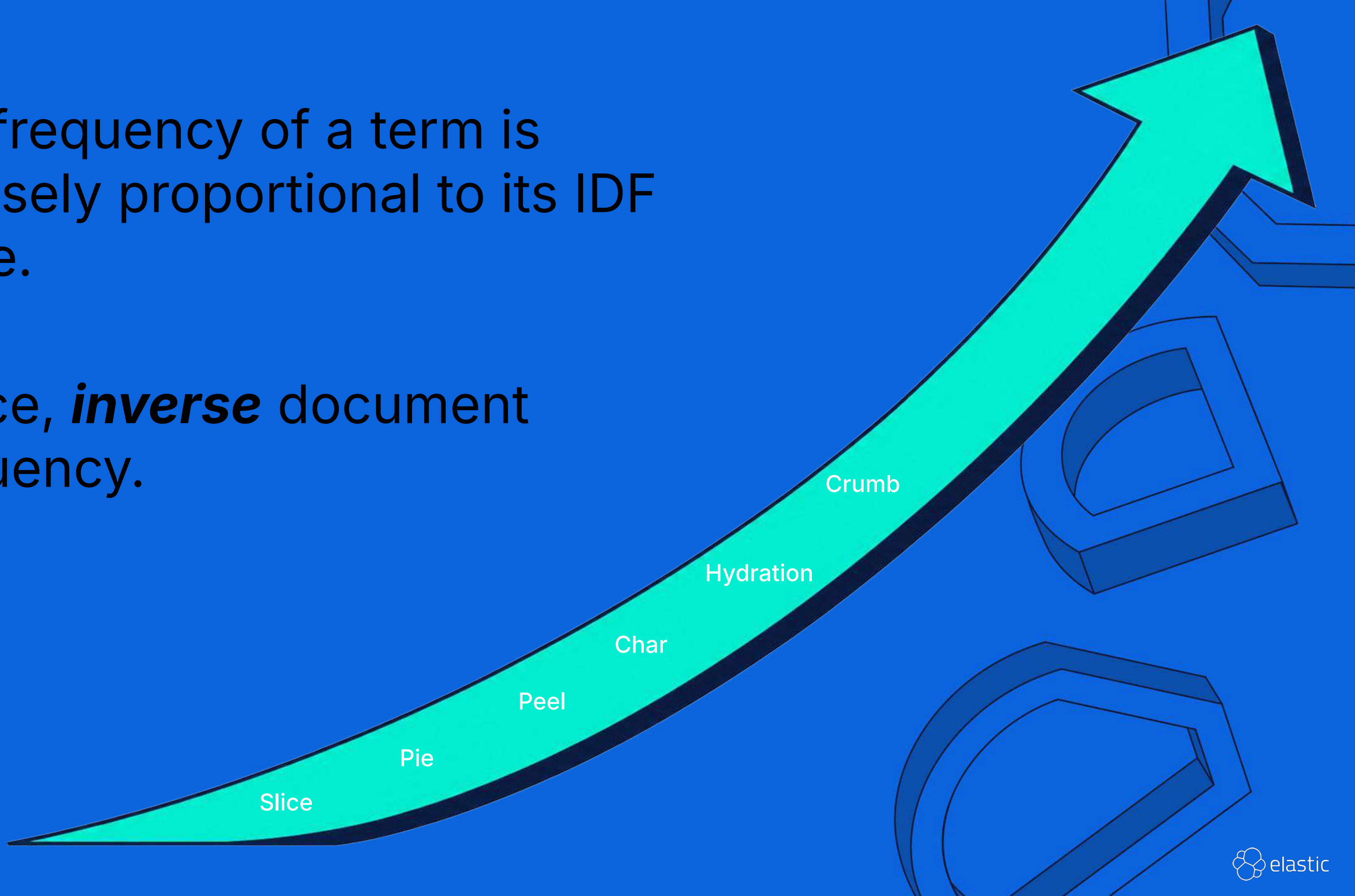
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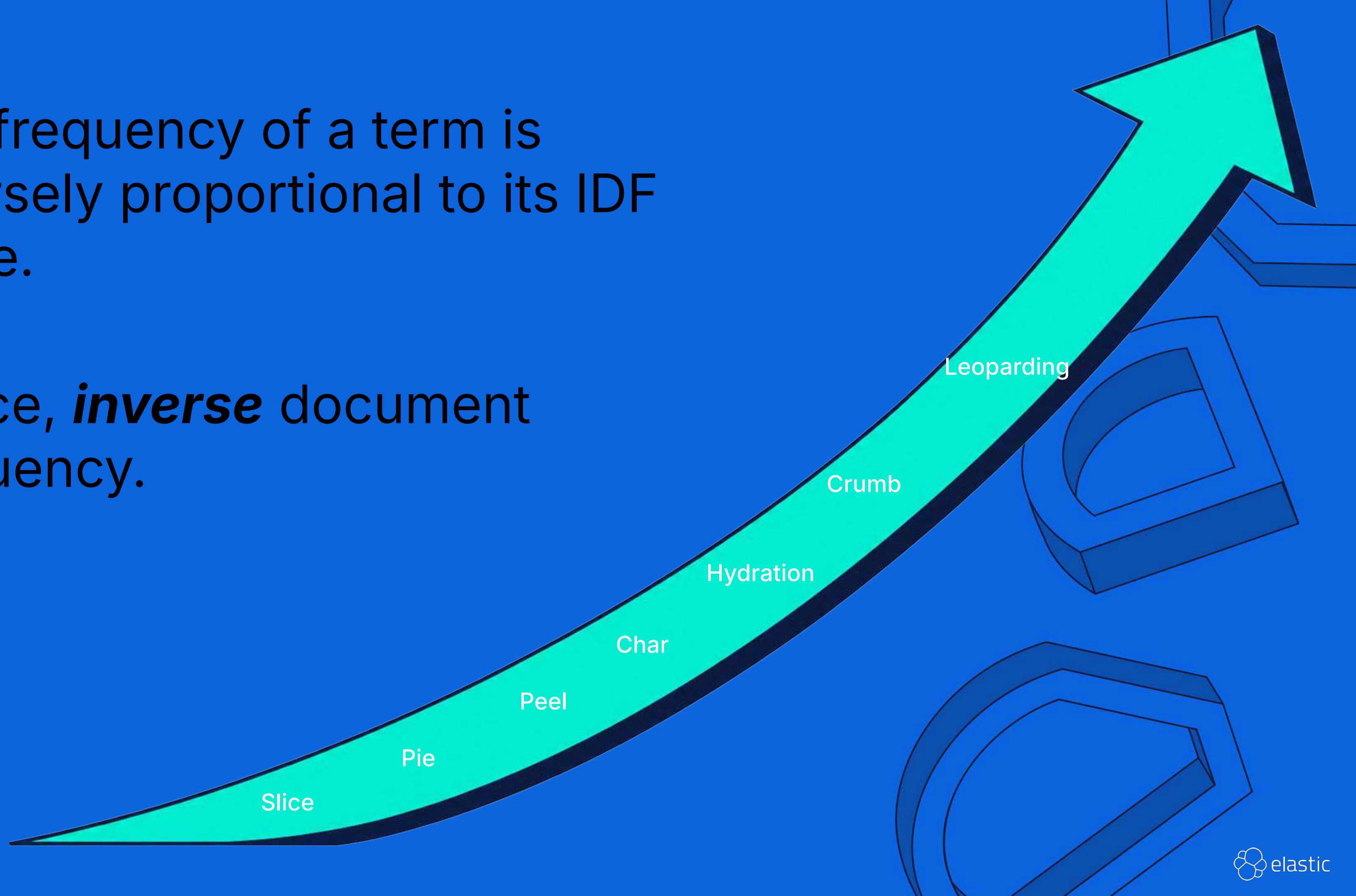
The frequency of a term is inversely proportional to its IDF score.

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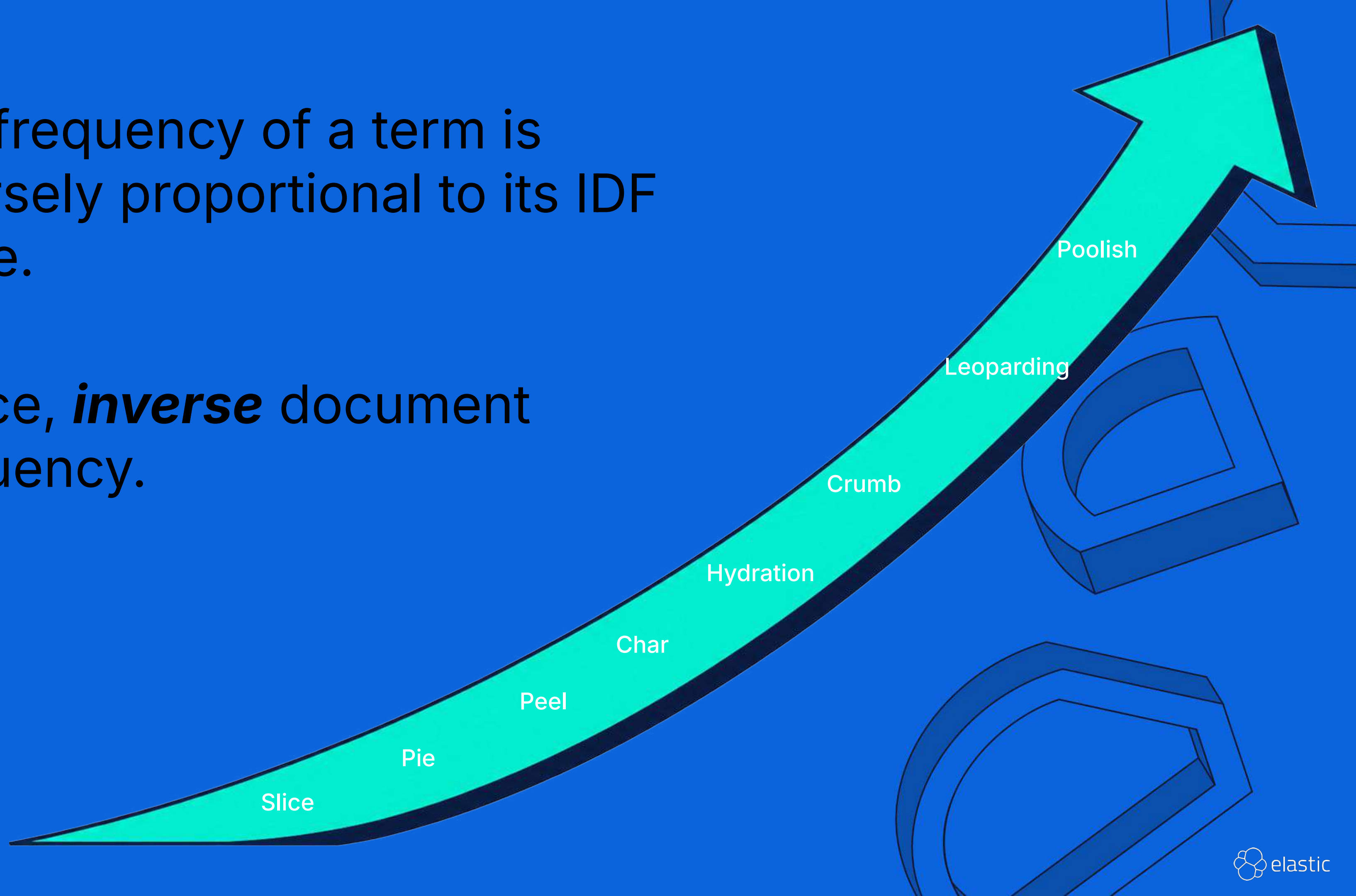
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inversely proportional to its IDF
score.

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frequency.



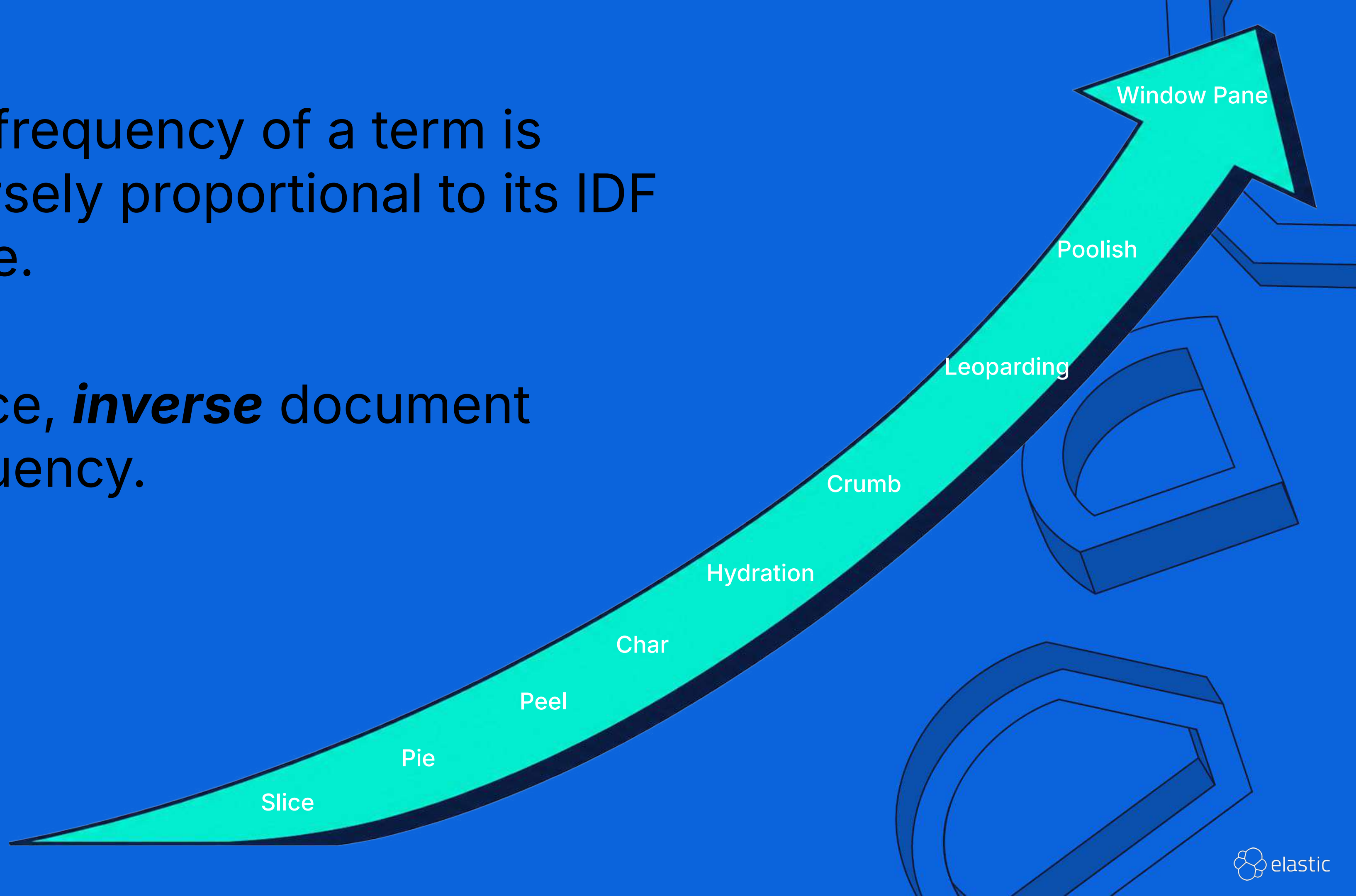
The frequency of a term is inversely proportional to its IDF score.

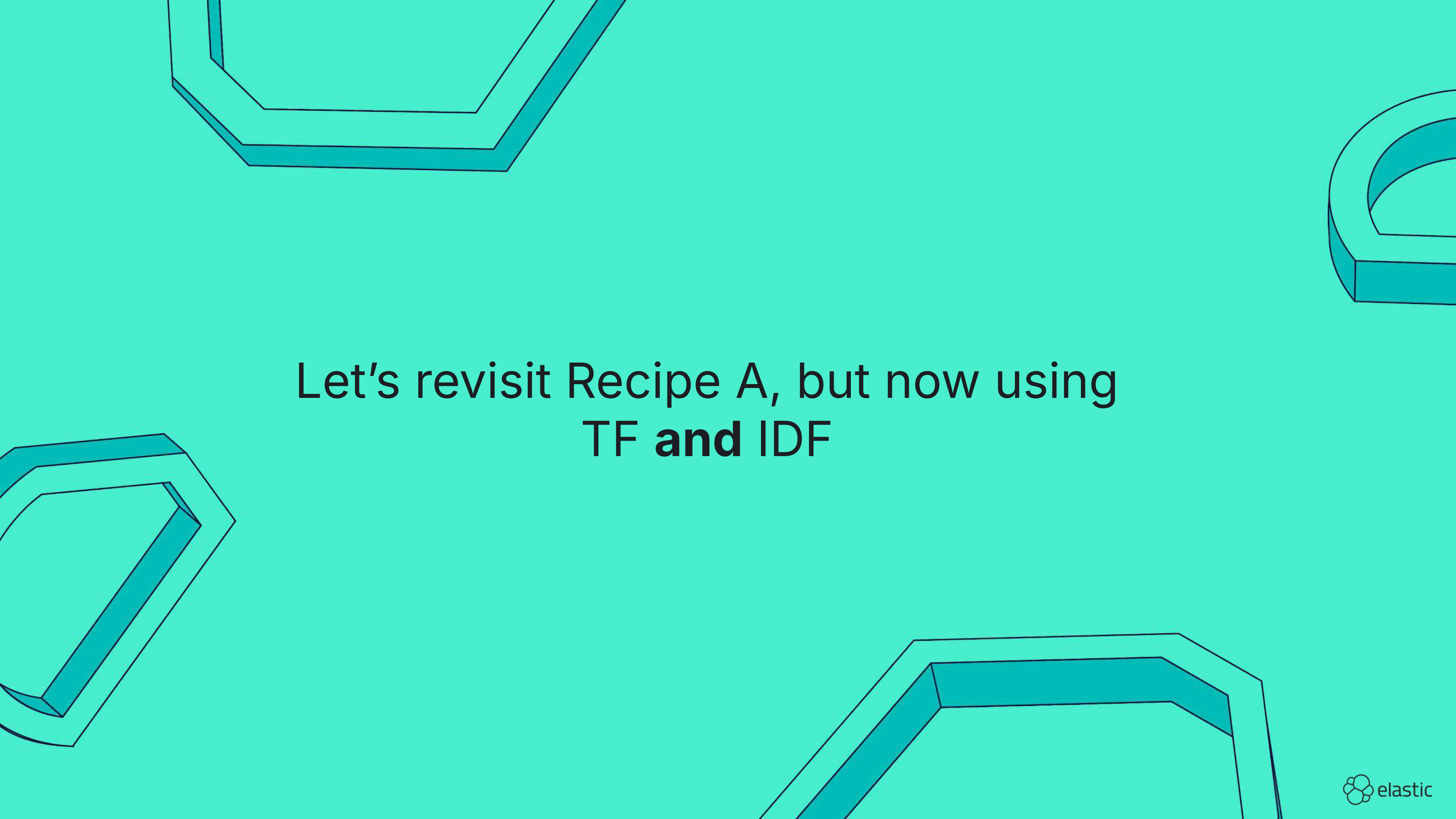
Hence, *inverse* document frequency.



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inversely proportional to its IDF
score.

Hence, *inverse* document
frequency.





Let's revisit Recipe A, but now using
TF and IDF

Recipe A (12)

The Most Perfect Vanilla Birthday Cake Recipe

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Ingredients:

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- 1 tbsp baking powder
- 1 tsp salt
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- 1 cup whole milk
- 2 tsp vanilla extract

Buttercream:

- 1½ cups unsalted butter, softened
- 5 cups powdered sugar
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- 2 tsp vanilla extract
- Pinch of salt

Instructions:

1. Preheat oven to 350°F. Grease and flour two 9-inch round pans.
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5. Cool completely before frosting.
6. For buttercream: beat butter until fluffy, add powdered sugar gradually, then cream, vanilla, and salt. Beat on high 3–4 minutes.
7. Frost between layers, then top and sides.

Recipe B

No-Fluff Artichoke Pizza Recipe

Ingredients:

- 1 lb pizza dough (or make your own — I use a 72-hour ferment)
- ¾ cup marinated artichoke hearts, drained and quartered
- 1½ cups shredded low-moisture mozzarella
- 2 cloves garlic, thinly sliced
- 2 tbsp good olive oil
- Zest of half a lemon
- Red pepper flakes, to taste
- Flaky salt

Instructions:

1. Preheat oven to 500°F (or as hot as it goes) with a baking steel or stone on the middle rack for at least 45 minutes.
2. Stretch dough thin to about 12 inches. Transfer to a floured peel or sheet of parchment.
3. Brush the surface with olive oil. Scatter mozzarella evenly, then distribute artichoke hearts and garlic slices.
4. Slide onto the steel/stone. Bake 8–10 minutes until the crust is charred in spots and the cheese is bubbling and just starting to brown.
5. Pull it out, hit it immediately with lemon zest, red pepper flakes, and flaky salt.



Recipe A

TERM	FREQUENCY (TF SCORE)
tasty	2
artichoke	2
pizza	1
recipe	7

Recipe B

TERM	FREQUENCY (TF SCORE)
tasty	0
artichoke	3
pizza	2
recipe	0

Recipe A (cake)

TERM	TF SCORE	IDF SCORE
tasty	2	
artichoke	2	
pizza	1	
recipe	7	

Recipe A (cake)

TERM	TF SCORE	IDF SCORE
tasty	2	0.2
artichoke	2	
pizza	1	
recipe	7	0.3

Recipe A (cake)

TERM	TF SCORE	IDF SCORE
tasty	2	0.2
artichoke	2	6.8
pizza	1	3.1
recipe	7	0.3

Recipe A (cake)

TERM	TF SCORE		IDF SCORE	PRODUCT	
tasty	2	X	0.2	=	0.4
artichoke	2	X	6.8	=	13.6
pizza	1	X	3.1	=	3.1
recipe	7	X	0.3	=	2.1

Recipe A (cake)

TERM	TF SCORE		IDF SCORE	PRODUCT	
tasty	2	X	0.2	=	0.4
					+
artichoke	2	X	6.8	=	13.6
					+
pizza	1	X	3.1	=	3.1
					+
recipe	7	X	0.3	=	2.1

Recipe A (cake)

TERM	TF SCORE	IDF SCORE	PRODUCT
tasty	2	X 0.2	= 0.4
artichoke	2	X 6.8	= 13.6
pizza	1	X 3.1	= 3.1
recipe	7	X 0.3	= 2.1

Final Score = 19.2

If we apply this same math to Recipe B
(which was **actually** for pizza) we get
a score of 26.6

Recipe A (19.2)

The Most Perfect Vanilla Birthday Cake Recipe

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Ingredients:

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Buttercream:

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4. Divide between pans. Bake 28–32 minutes until a toothpick comes out clean.
5. Cool completely before frosting.
6. For buttercream: beat butter until fluffy, add powdered sugar gradually, then cream, vanilla, and salt. Beat on high 3–4 minutes.
7. Frost between layers, then top and sides.

Recipe B (26.6)

No-Fluff Artichoke Pizza Recipe

Ingredients:

- 1 lb pizza dough (or make your own — I use a 72-hour ferment)
- ¾ cup marinated artichoke hearts, drained and quartered
- 1½ cups shredded low-moisture mozzarella
- 2 cloves garlic, thinly sliced
- 2 tbsp good olive oil
- Zest of half a lemon
- Red pepper flakes, to taste
- Flaky salt

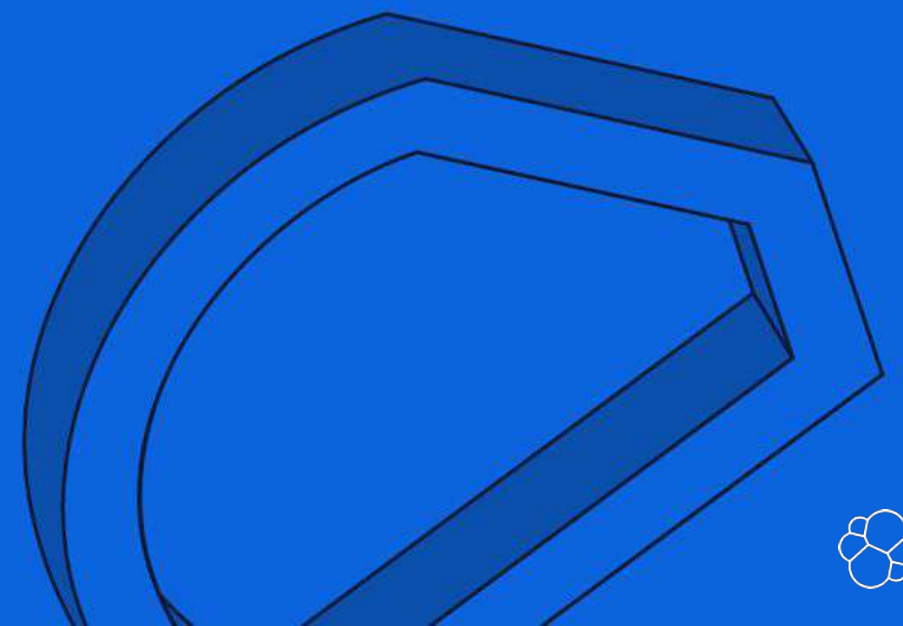
Instructions:

1. Preheat oven to 500°F (or as hot as it goes) with a baking steel or stone on the middle rack for at least 45 minutes.
2. Stretch dough thin to about 12 inches. Transfer to a floured peel or sheet of parchment.
3. Brush the surface with olive oil. Scatter mozzarella evenly, then distribute artichoke hearts and garlic slices.
4. Slide onto the steel/stone. Bake 8–10 minutes until the crust is charred in spots and the cheese is bubbling and just starting to brown.
5. Pull it out, hit it immediately with lemon zest, red pepper flakes, and flaky salt.



Level 7: BM25

BM25



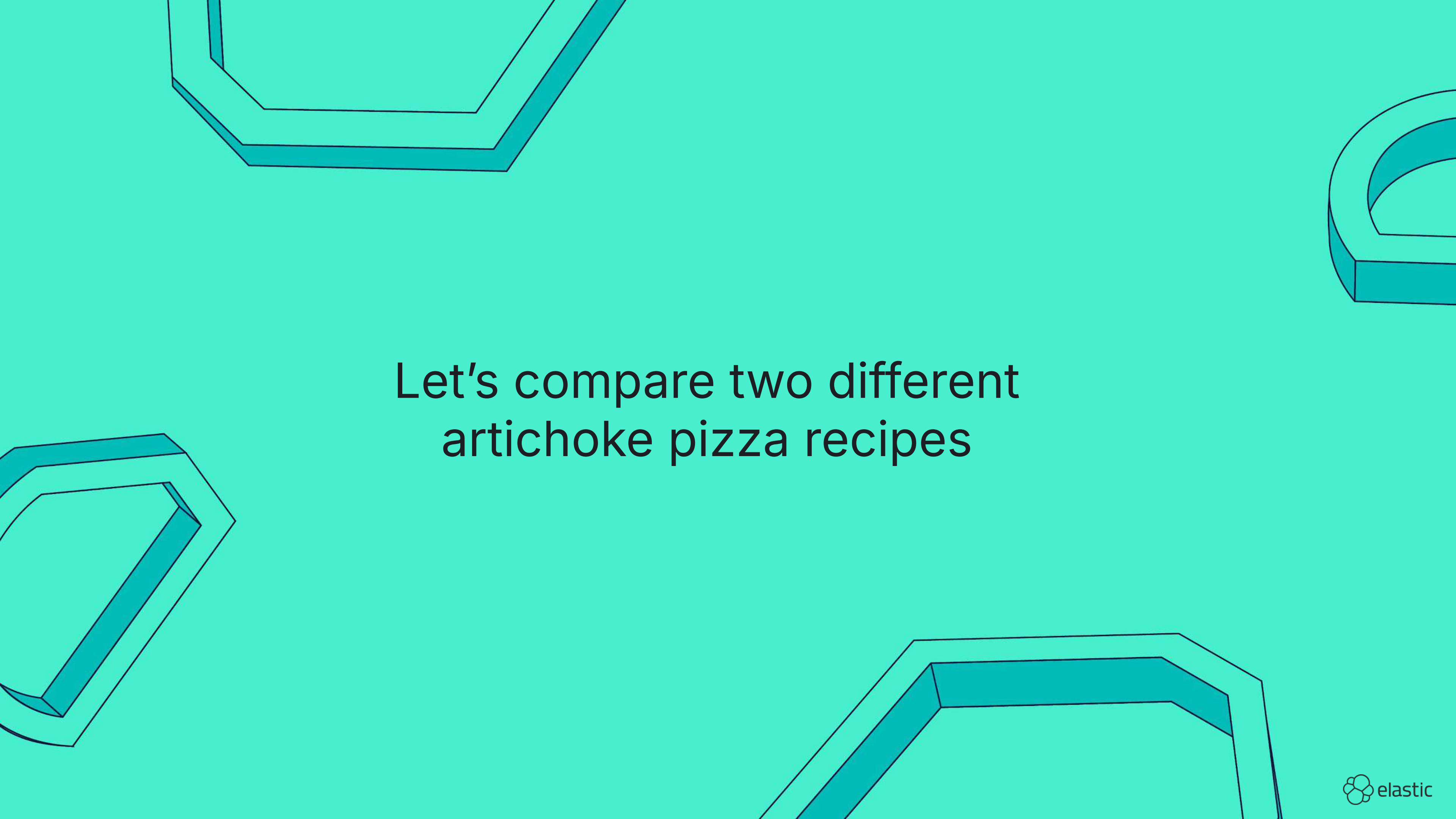
BM25

Best Match, Version 25

BM25

Best Match, Version 25

TF + IDF + some more bells & whistles



Let's compare two different
artichoke pizza recipes

Recipe B

No-Fluff Artichoke Pizza Recipe

Ingredients:

- 1 lb pizza dough (or make your own — I use a 72-hour ferment)
- $\frac{3}{4}$ cup marinated artichoke hearts, drained and quartered
- $1\frac{1}{2}$ cups shredded low-moisture mozzarella
- 2 cloves garlic, thinly sliced
- 2 tbsp good olive oil
- Zest of half a lemon
- Red pepper flakes, to taste
- Flaky salt

Instructions:

1. Preheat oven to 500°F (or as hot as it goes) with a baking steel or stone on the middle rack for at least 45 minutes.
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5. Pull it out, hit it immediately with lemon zest, red pepper flakes, and flaky salt.



Recipe C

No-Fluff Artichoke Pizza Recipe

Ingredients:

- 1 lb pizza dough (or make your own — I use a 72-hour ferment)
- $\frac{3}{4}$ cup marinated artichoke hearts, drained and quartered
- $1\frac{1}{2}$ cups shredded low-moisture mozzarella
- 2 cloves garlic, thinly sliced
- 2 tbsp good olive oil
- Zest of half a lemon
- Red pepper flakes, to taste
- Flaky salt

Instructions:

1. Preheat oven to 500°F (or as hot as it goes) with a baking steel or stone on the middle rack for at least 45 minutes.
2. Stretch dough thin to about 12 inches. Transfer to a floured peel or sheet of parchment.
3. Brush the surface with olive oil. Scatter mozzarella evenly, then distribute artichoke hearts and garlic slices.
4. Slide onto the steel/stone. Bake 8–10 minutes until the crust is charred in spots and the cheese is bubbling and just starting to brown.
5. Pull it out, hit it immediately with lemon zest, red pepper flakes, and flaky salt.



Other Artichoke-Based Recipes:

- [Braised Artichoke Hearts with Lemon and Dill](#)
- [Crispy Fried Artichokes with Garlic Aioli](#)
- [Artichoke and White Bean Soup](#)

Recipe B

No-Fluff Artichoke Pizza Recipe

Ingredients:

- 1 lb pizza dough (or make your own — I use a 72-hour ferment)
- $\frac{3}{4}$ cup marinated artichoke hearts, drained and quartered
- $1\frac{1}{2}$ cups shredded low-moisture mozzarella
- 2 cloves garlic, thinly sliced
- 2 tbsp good olive oil
- Zest of half a lemon
- Red pepper flakes, to taste
- Flaky salt

Instructions:

1. Preheat oven to 500°F (or as hot as it goes) with a baking steel or stone on the middle rack for at least 45 minutes.
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Other Artichoke-Based Recipes:

- [Braised Artichoke Hearts with Lemon and Dill](#)
- [Crispy Fried Artichokes with Garlic Aioli](#)
- [Artichoke and White Bean Soup](#)

Recipe B

No-Fluff Artichoke Pizza Recipe

Ingredients:

- 1 lb pizza dough (or make your own — I use a 72-hour ferment)
- ¾ cup marinated artichoke hearts, drained and quartered
- 1½ cups shredded low-moisture mozzarella
- 2 cloves garlic, thinly sliced
- 2 tbsp good olive oil
- Zest of half a lemon
- Red pepper flakes, to taste
- Flaky salt

Instructions:

1. Preheat oven to 500°F (or as hot as it goes) with a baking steel or stone on the middle rack for at least 45 minutes.
2. Stretch dough thin to about 12 inches. Transfer to a floured peel or sheet of parchment.
3. Brush the surface with olive oil. Scatter mozzarella evenly, then distribute artichoke hearts and garlic slices.
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5. Pull it out, hit it immediately with lemon zest, red pepper flakes, and flaky salt.



Recipe D

The Only Artichoke Pizza Recipe You'll Ever Need

I spent the summer of 2019 in Italy, and I'm not exaggerating when I say it ruined me for pizza forever — in the best possible way.

It started in Naples, obviously. My first night I walked into a tiny place off Via dei Tribunali with no signage and plastic chairs on the sidewalk. I ordered a margherita and it arrived in about ninety seconds — blistered, soupy in the center, with mozzarella that tasted like it had been alive that morning. I ate the whole thing standing up because I couldn't wait for a table.

Over the next few weeks I worked my way through every regional style I could find. In Rome I had pizza al taglio from Bonci — those thick, airy rectangles with toppings I'd never considered. Potato and rosemary. Zucchini flower. Mortadella and burrata, which honestly should be illegal. In Bologna I had a pizza with pistachio pesto that I still think about at least once a week. In Sicily I tried sfincione — spongy, oily, covered in breadcrumbs and anchovy — and liked it way more than I expected to.

But the pizza that stuck with me most was one I had in a small trattoria outside Florence. It was simple: thin Roman-style crust, olive oil, garlic, mozzarella, and marinated artichoke hearts with a squeeze of lemon on top. That was it. No meat, no arugula piled on after, no drizzle of anything truffle-adjacent. Just artichokes doing what artichokes do when you leave them alone on good dough. I ordered a second one. The waiter laughed.

When I got home I spent months trying to recreate it. The crust was the hardest part — I wanted that Roman cracker-thin base, not the Neapolitan puff. The artichokes had to be marinated, not canned in brine (huge difference). And the garlic had to be sliced thin and placed raw on the dough so it roasted in the oven rather than sautéed beforehand. It took maybe a dozen attempts before I got something that made me feel like I was back in that trattoria, swatting away wasps in the late afternoon heat.

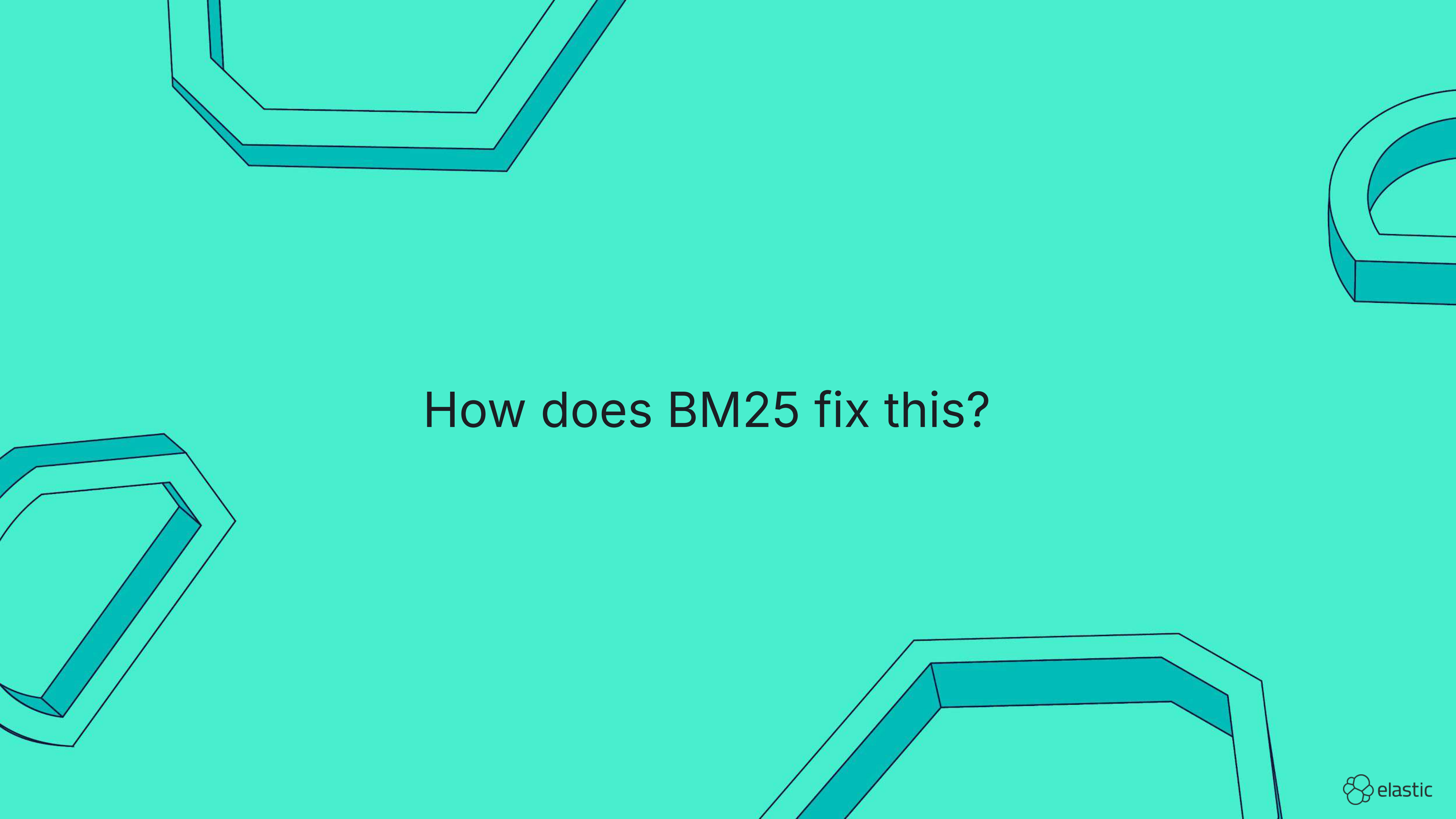


Ingredients:

- 1 lb pizza dough (or make your own — I use a 72-hour ferment)
- ¾ cup marinated artichoke hearts, drained and quartered
- 1½ cups shredded low-moisture mozzarella
- 2 cloves garlic, thinly sliced
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Instructions:

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5. Pull it out, hit it immediately with lemon zest, red pepper flakes, and flaky salt.

The background features several abstract, teal-colored geometric shapes. In the top left, there is a complex, multi-layered shape resembling a stylized 'L' or a corner. In the top right, a curved, shell-like shape is visible. On the left side, there is a shape that looks like a stylized 'D' or a partial circle. In the bottom right, there is a long, horizontal, multi-layered shape. All these shapes are composed of multiple parallel lines, creating a sense of depth and layering.

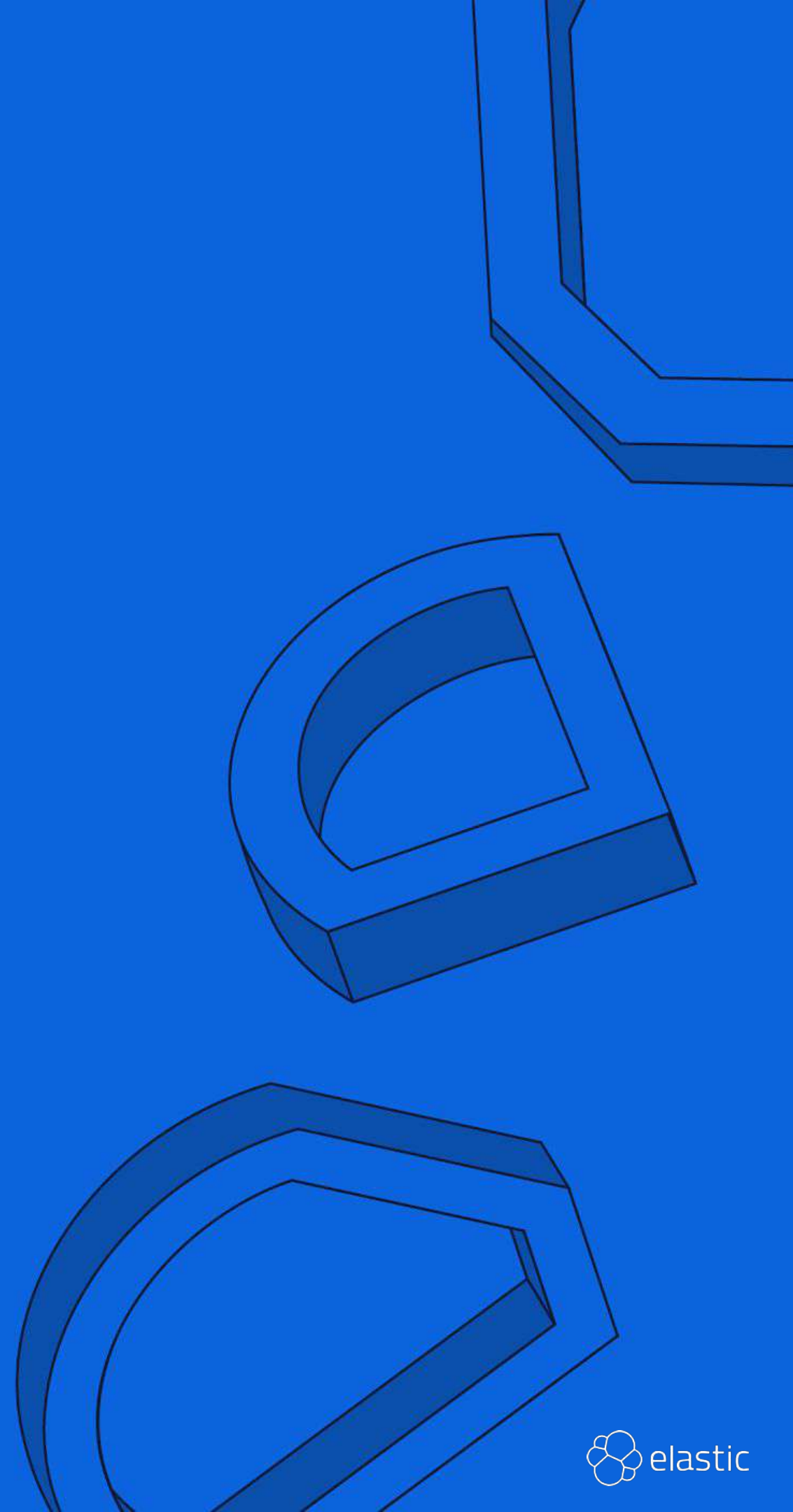
How does BM25 fix this?

Improvements over TF + IDF

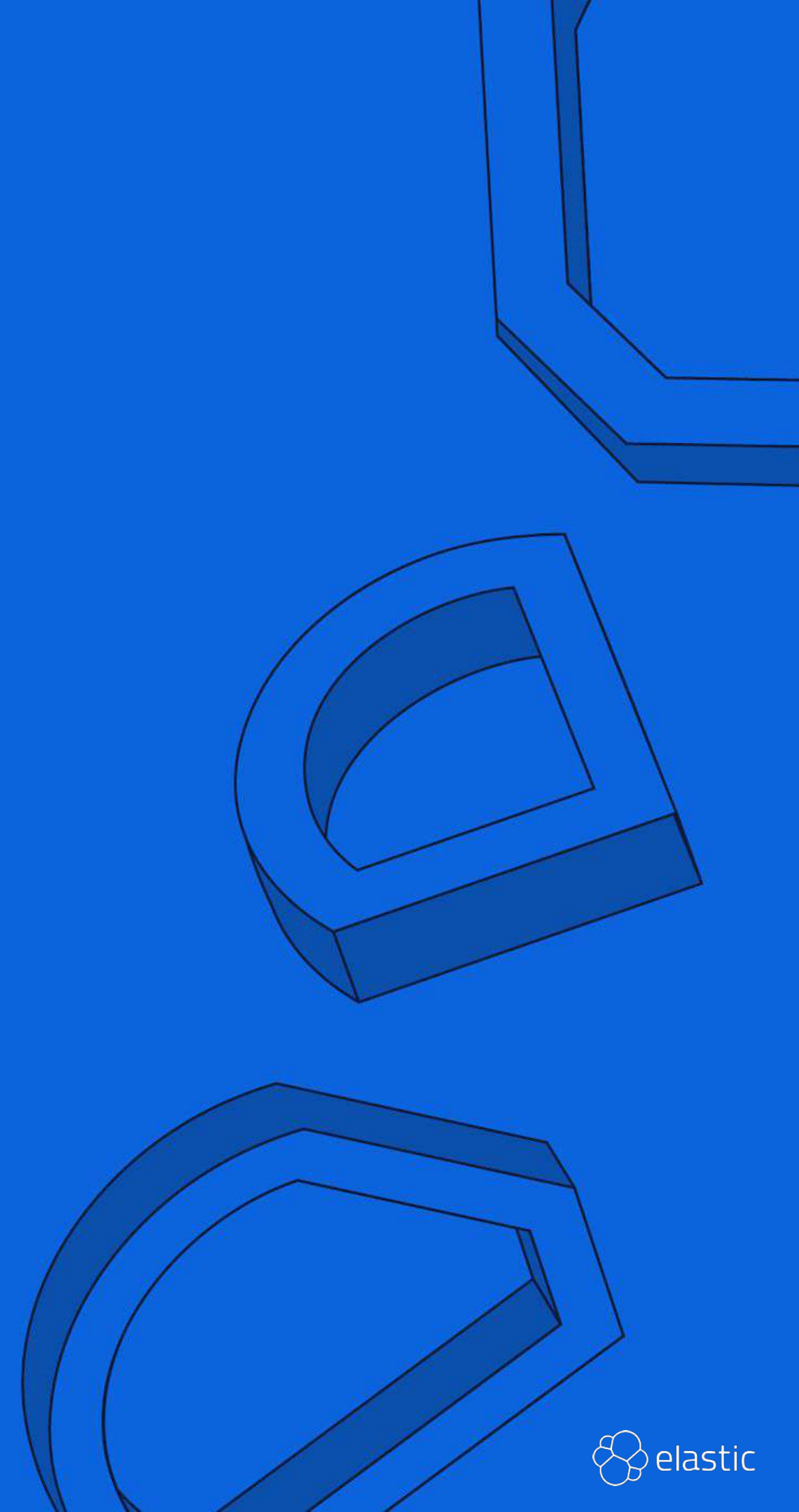
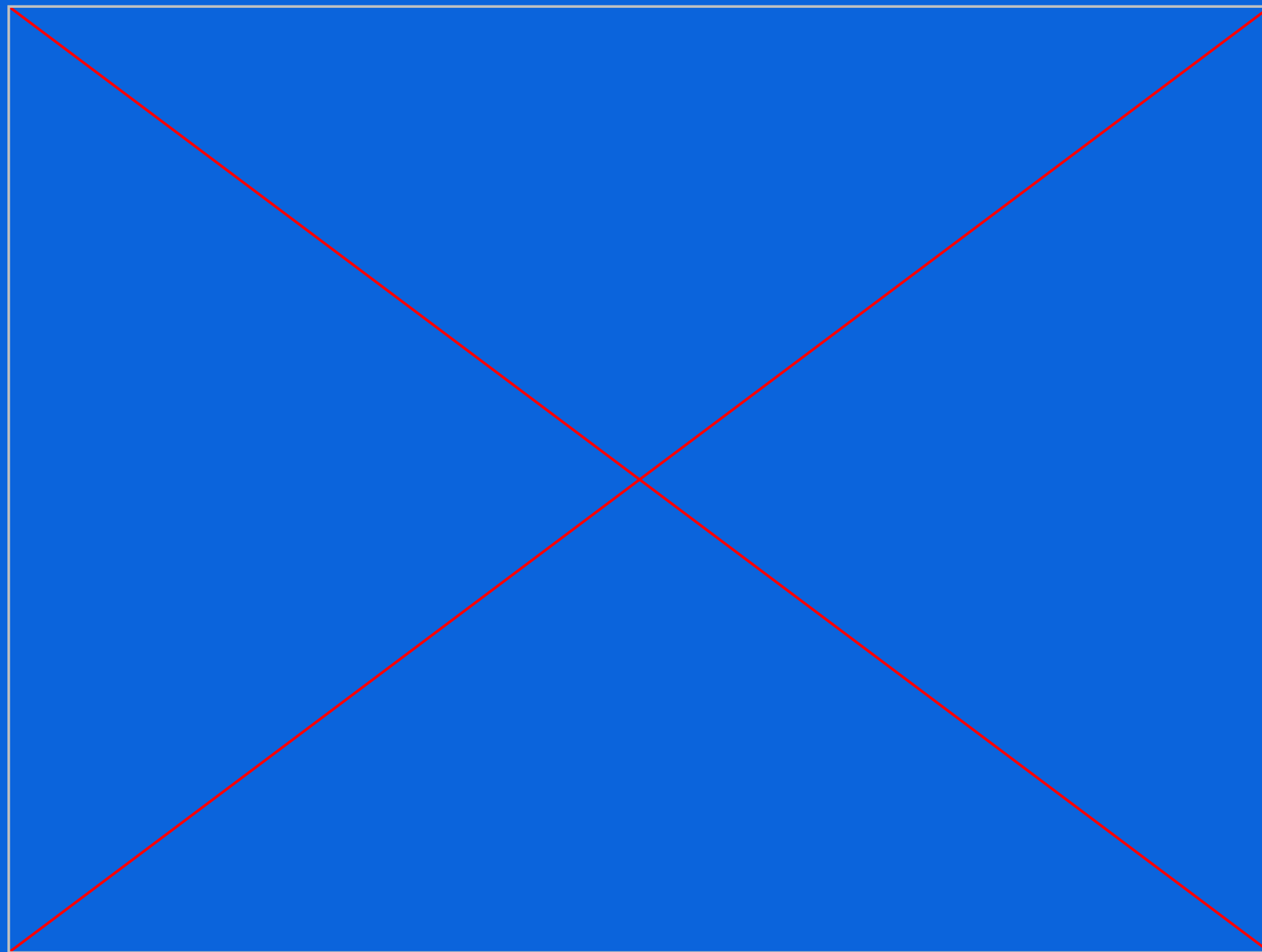
Improvements over TF + IDF

+ Saturation curve is applied to how term frequencies are calculated

Ok, but what is a saturation curve?



Ok, but what is a saturation curve?



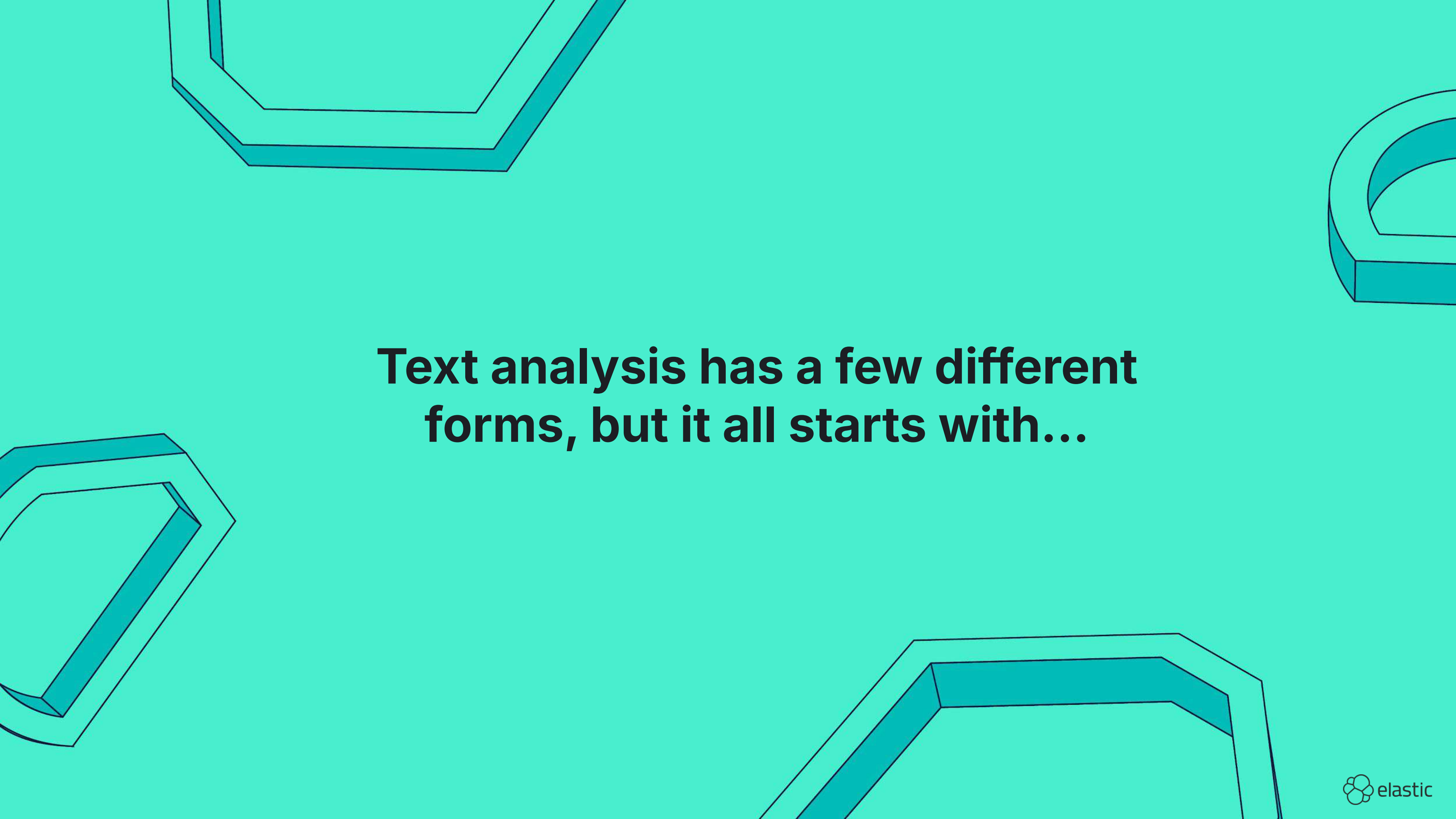
Improvements over TF + IDF

+ Saturation curve is applied to how term frequencies are calculated

Improvements over TF + IDF

- + Saturation curve is applied to how term frequencies are calculated
- + Takes document length into account and adjusts final scores accordingly

Level 8: Text Analysis

The background features several abstract, teal-colored geometric shapes. In the top left, there's a complex, multi-layered shape resembling a stylized 'E' or a series of nested lines. In the top right, a curved, shell-like shape is visible. On the left side, there's a shape that looks like a stylized 'L' or a corner of a cube. At the bottom, there are more angular, layered shapes. The overall aesthetic is modern and minimalist.

**Text analysis has a few different
forms, but it all starts with...**

Text Analysis

8.1 — Tokenization

The background features several abstract, teal-colored geometric shapes. In the top left, there is a complex, multi-layered shape resembling a stylized 'L' or a corner. In the top right, a curved, shell-like shape is visible. On the left side, there is a shape that looks like a stylized 'C' or a partial circle. At the bottom, there are more angular, layered shapes. The overall aesthetic is modern and minimalist.

**Tokenization is all about
breaking down a query into
individual tokens.**

Tokenization

1 Hyphens

brick-oven pizza

(split on hyphen)

brick

oven

pizza

(keep hyphenated term)

brick-oven

pizza

Tokenization

1 Hyphens

brick-oven pizza

(split on hyphen)

brick

oven

pizza

(keep hyphenated term)

brick-oven

pizza

2 Punctuation

When you tokenize

How to make pizza?

should the pizza token
include the question mark?

Include punctuation

How

to

make

pizza?

Remove punctuation

How

to

make

pizza

Tokenization

1 Hyphens

brick-oven pizza

(split on hyphen)

brick

oven

pizza

(keep hyphenated term)

brick-oven

pizza

2 Punctuation

When you tokenize

How to make pizza?

should the pizza token
include the question mark?

Include punctuation

How

to

make

pizza?

Remove punctuation

How

to

make

pizza

3 Apostrophes

Danny's Pizza

(split on apostrophe)

Danny

Pizza

(keep apostrophe)

Danny's

Pizza

Tokenization Examples

```
POST _analyze
{
  "tokenizer": "thai",
  "text": "การที่ได้ต้องแสดงว่างานดี"
}

// Output Tokens
[ การ, ที่, ได้, ต้อง, แสดง, ว่า, งาน, ดี ]
```

Tokenization Examples

```
POST _analyze
{
  "tokenizer": "thai",
  "text": "การที่ได้ต้องแสดงว่างานดี"
}
```

```
// Output Tokens
[ การ, ที่, ได้, ต้อง, แสดง, ว่า, งาน, ดี ]
```

```
POST _analyze
{
  "tokenizer": "path_hierarchy",
  "text": "/recipes/vegetarian/vegetable-medley-pizza"
}
```

```
// Output Tokens
[/recipes, /recipes/vegetarian, /recipes/vegetarian/vegetable-medley-pizza]
```

Tokenization Examples

```
POST _analyze
{
  "tokenizer": "thai",
  "text": "การที่ได้ต้องแสดงว่างานดี"
}

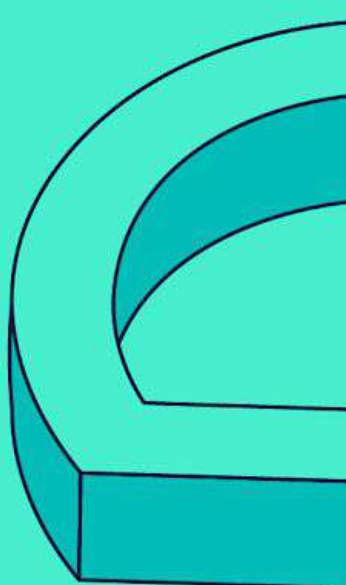
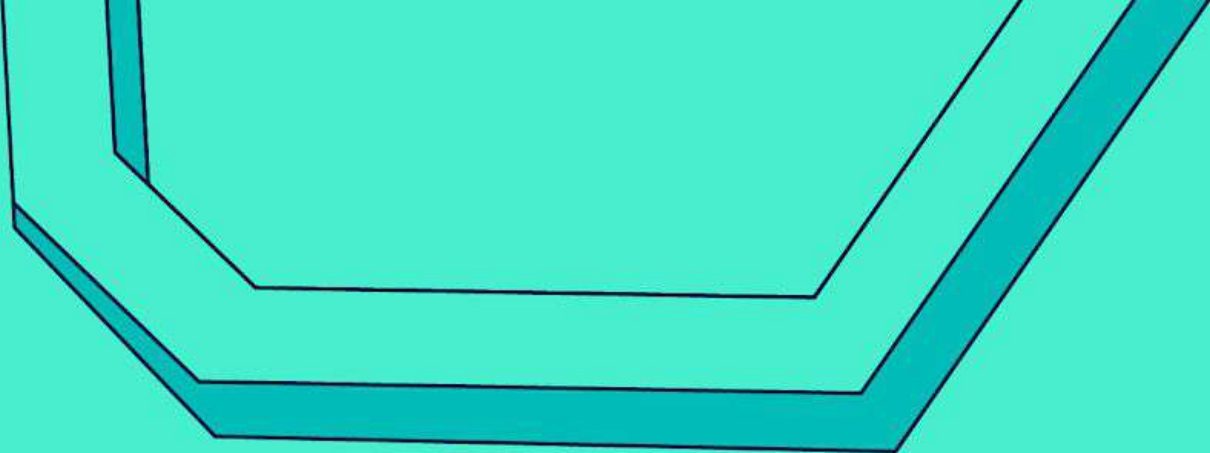
// Output Tokens
[ การ, ที่, ได้, ต้อง, แสดง, ว่า, งาน, ดี ]

POST _analyze
{
  "tokenizer": "path_hierarchy",
  "text": "/recipes/vegetarian/vegetable-medley-pizza"
}

// Output Tokens
[/recipes, /recipes/vegetarian, /recipes/vegetarian/vegetable-medley-pizza]

POST _analyze
{
  "tokenizer": "uax_url_email",
  "text": "Email me at danny.smith@dannys-pizza.com"
}

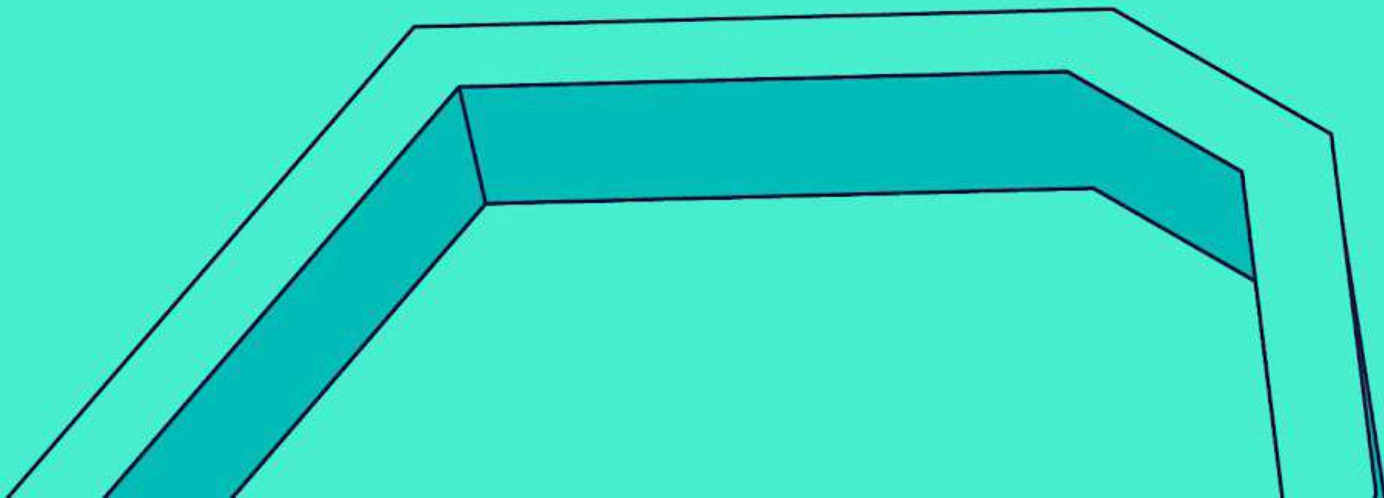
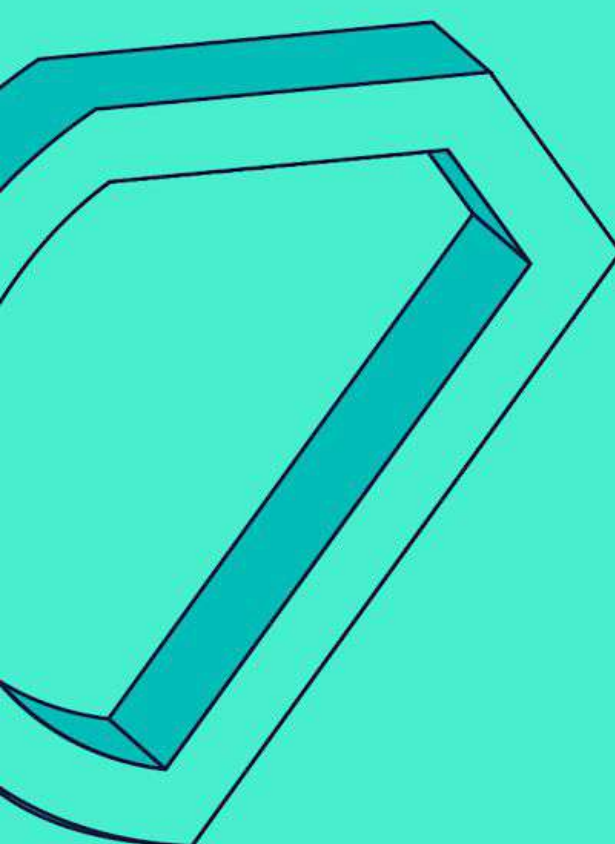
// Output Tokens
[Email, me, at, danny.smith@dannys-pizza.com]
```



Text Analysis

8.1 — Tokenization

8.2 — Stop Words

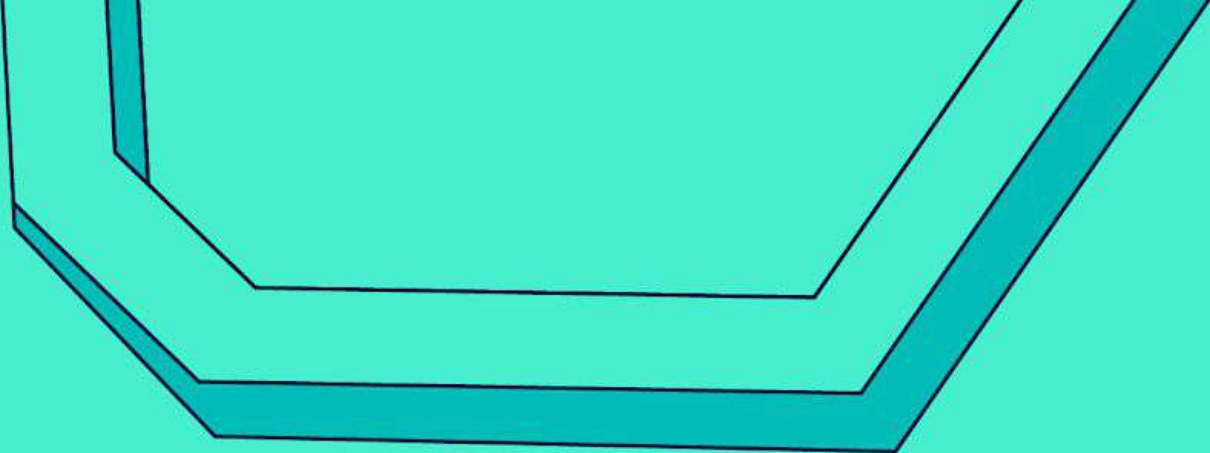


Stop Words

- "the", "of", "and", "as", & "are"

Stop Words

- "the", "of", "and", "as", & "are"
- Unhelpful filler

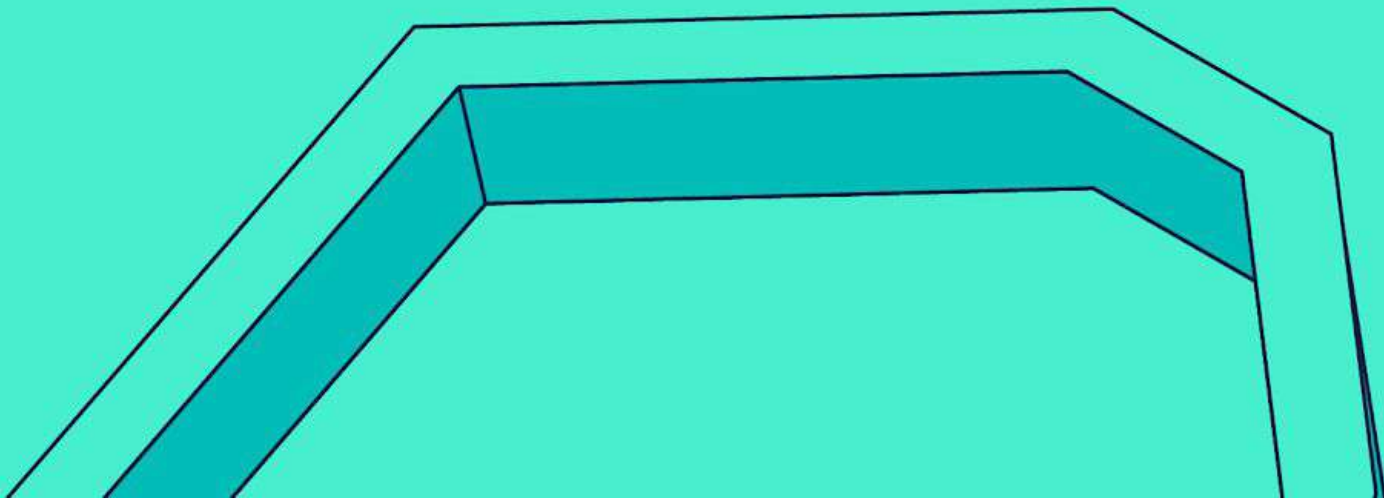


Text Analysis

8.1 — Tokenization

8.2 — Stop Words

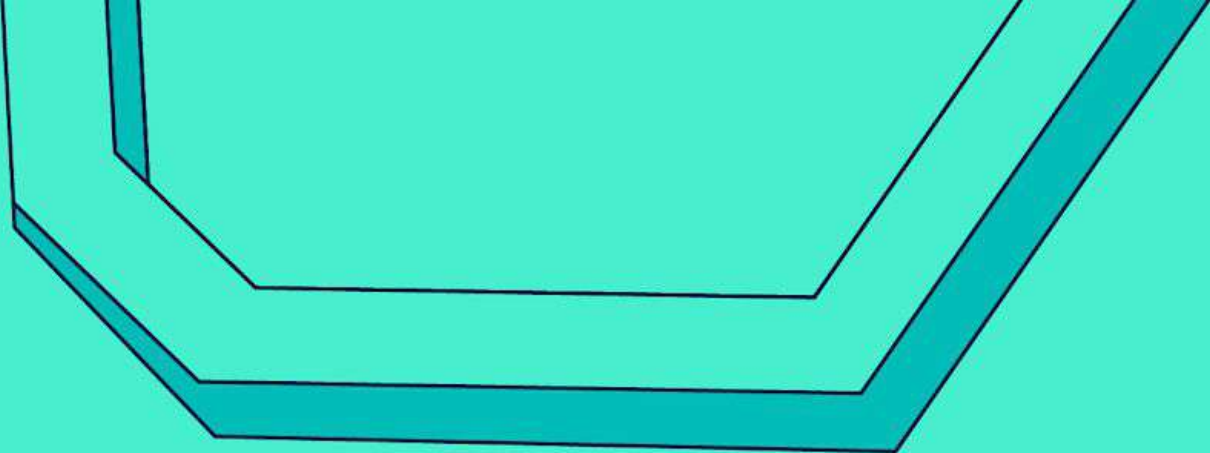
8.3 — Stemming



Stemming

```
GET /_analyze
{
  "tokenizer": "standard",
  "filter": ["stemmer"],
  "text": "charred pizza"
}
```

```
// Output Tokens
[char, pizza]
```



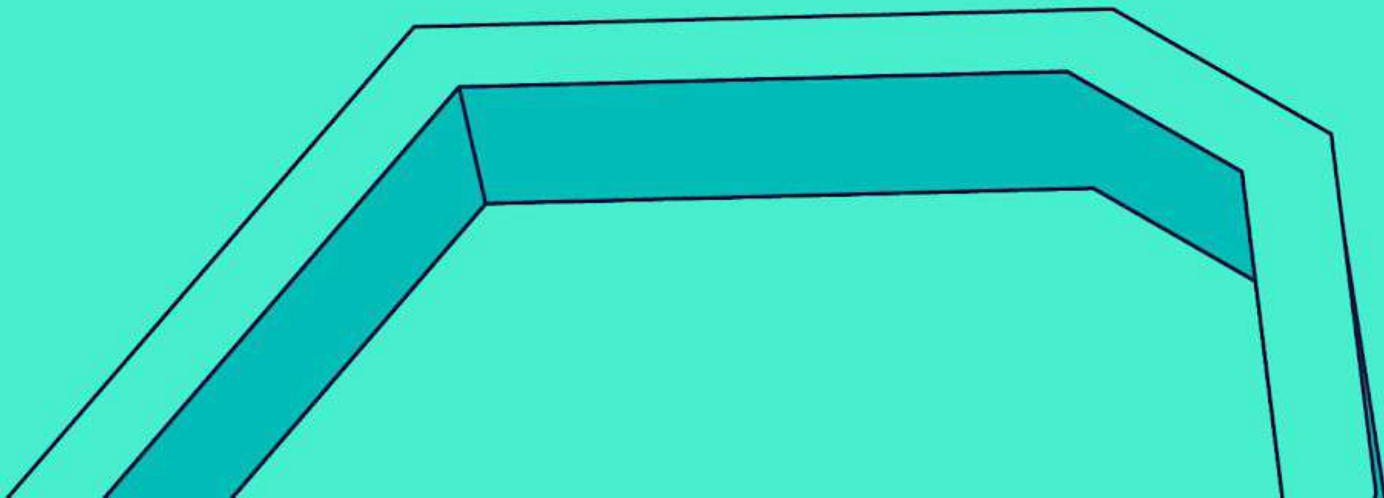
Text Analysis

8.1 — Tokenization

8.2 — Stop Words

8.3 — Stemming

8.4 — Synonyms



Synonyms

It shouldn't matter whether I'm searching for a New York, NY, or NYC style pizza recipe. Synonyms can be registered in your Elastic search system in a few different ways.

Synonyms

It shouldn't matter whether I'm searching for a New York, NY, or NYC style pizza recipe. Synonyms can be registered in your Elastic search system in a few different ways.

- synonyms API
- synonyms file
- inline w/ token filter

Synonyms

```
// synonyms API
"filter": {
  "synonyms_filter": {
    "type": "synonym",
    "synonyms_set": "my-synonym-set",
    "updateable": true
  }
}

// synonyms file
"filter": {
  "synonyms_filter": {
    "type": "synonym",
    "synonyms_path": "analysis/synonym-set.txt"
  }
}

// inline
"filter": {
  "synonyms_filter": {
    "type": "synonym",
    "synonyms": ["New York => NY", "NYC"]
  }
}
```

Text Analysis

8.1 — Tokenization

8.2 — Stop Words

8.3 — Stemming

8.4 — Synonyms

8.5 — Spell Check

Spell Check

If a user mistypes their search query for pizza and instead types in p-i-z-a, they should still get the same results. There are few ways in Elastic to perform spell correction.

Spell Check

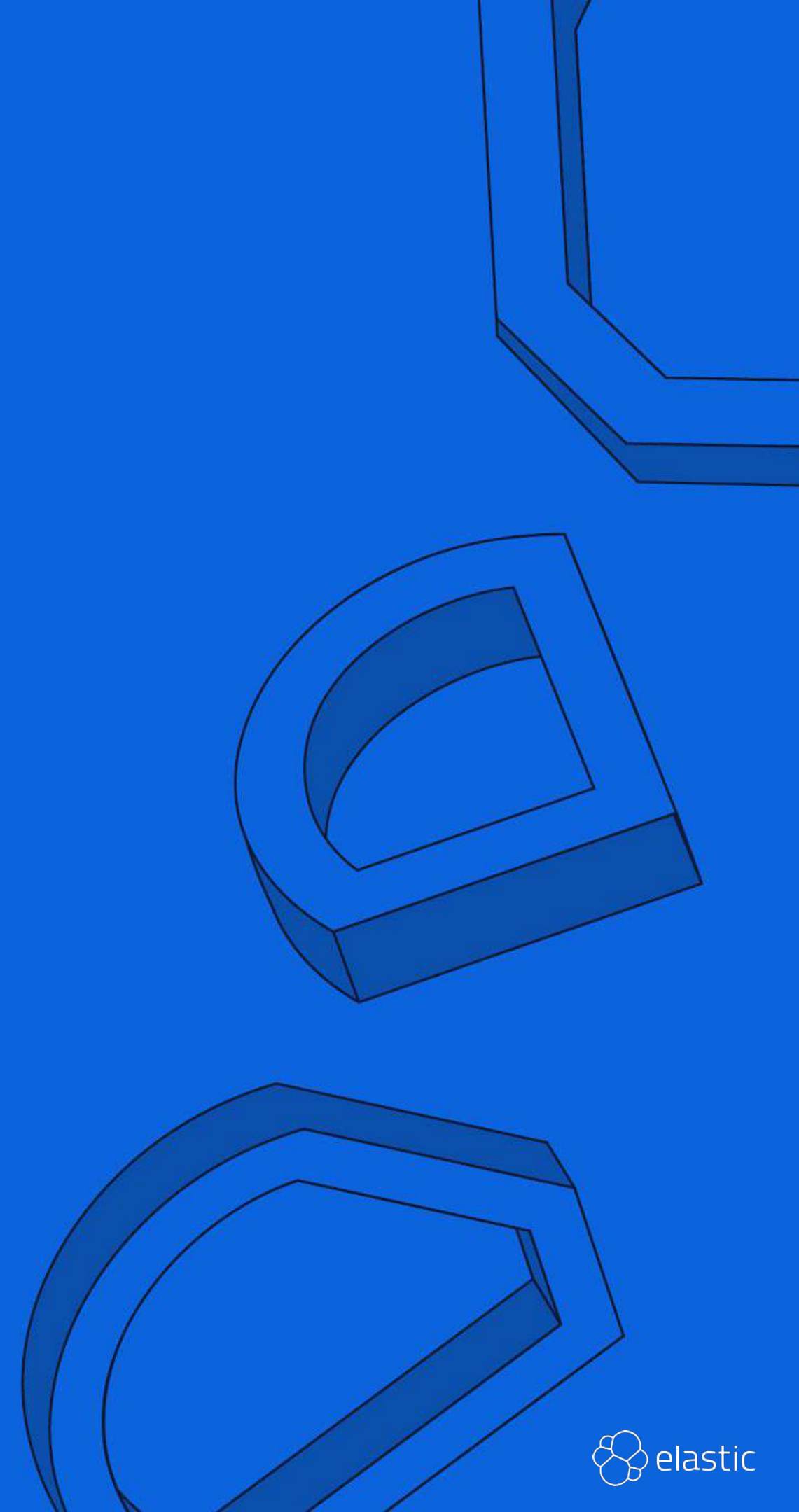
If a user mistypes their search query for pizza and instead types in p-i-z-a, they should still get the same results. There are few ways in Elastic to perform spell correction.

- register incorrect spellings as synonyms
- fuzzy queries
- suggesters (did you mean to say...)
- phonetic token filter plugin

Text Analysis — Putting It All Together

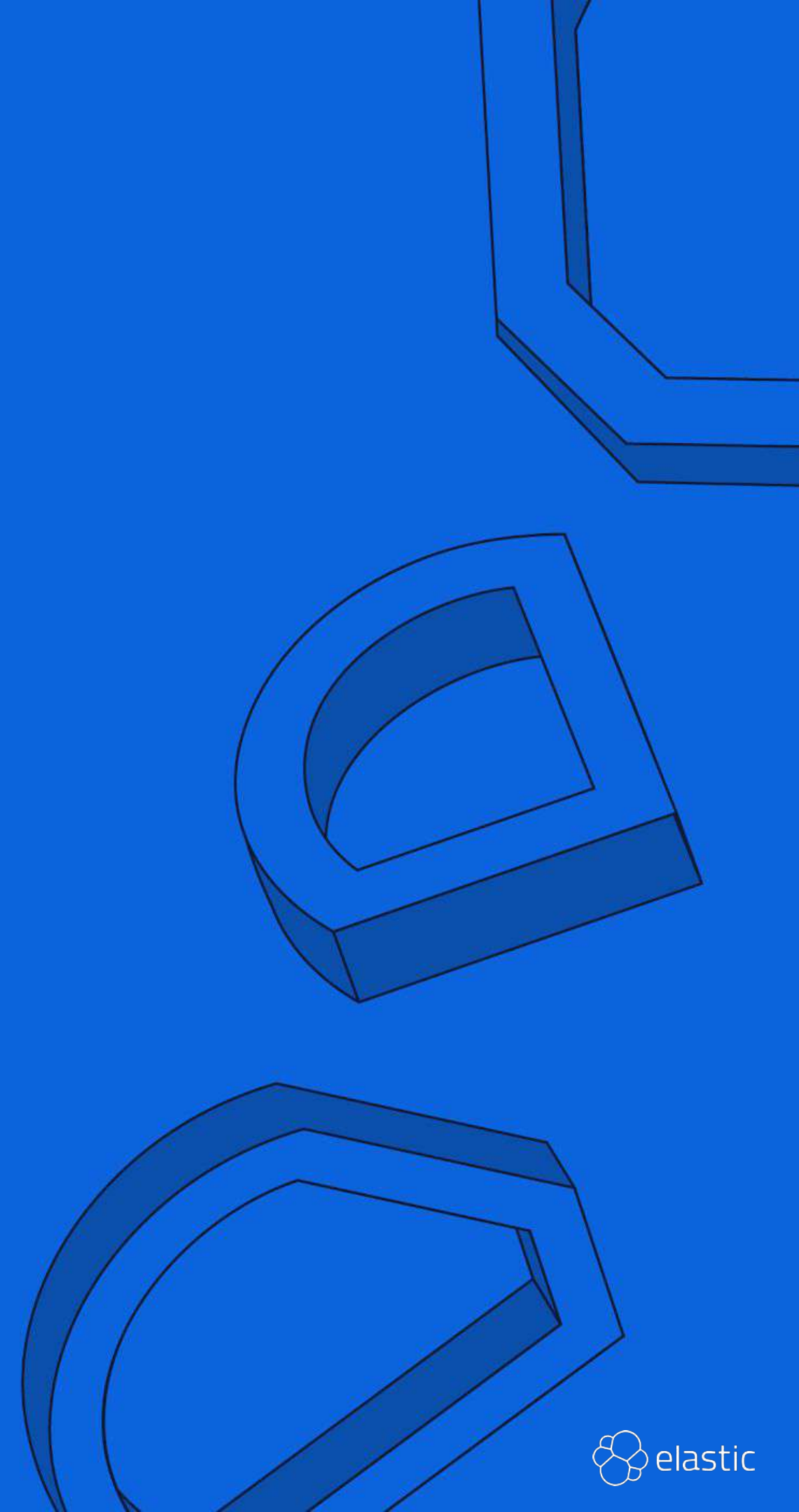
I search for...

- “ the best wood fired neapolitan pie”



I search for...

- “~~the~~ best wood fired neapolitan pie”



I search for...

- "~~the~~ best wood fired neapolitin pie"
- "best wood fired neapolitin pie"

I search for...

- "~~the~~ best wood fired neapolitin pie"
- "best wood fire~~d~~ neapolitin pie"

I search for...

- "~~the~~ best wood fired neapolitin pie"
- "best wood fire~~d~~ neapolitin pie"
- "best wood fire neapolitin pie"

I search for...

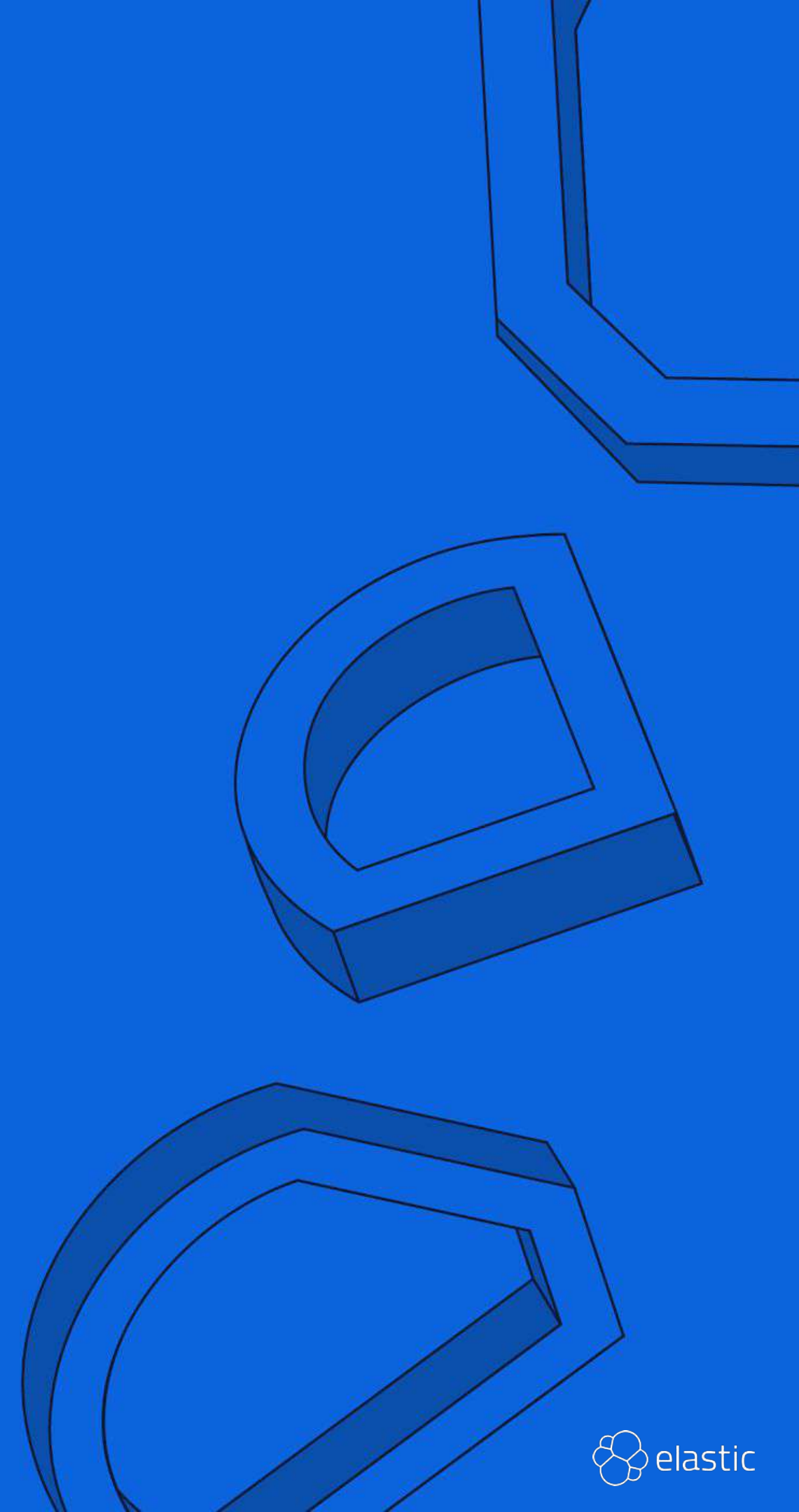
- "~~the~~ best wood fired neapolitin pie"
- "best wood fire~~d~~ neapolitin pie"
- "best wood fire neapolitin ~~pie~~"

I search for...

- "~~the~~ best wood fired neapolitin pie"
- "best wood fire~~d~~ neapolitin pie"
- "best wood fire neapolitin ~~pie~~"
- "best wood fire neapolitin pizza"

I search for...

- "~~the~~ best wood fired neapolitin pie"
- "best wood fire~~d~~ neapolitin pie"
- "best wood fire neapolitin ~~pie~~"
- "best wood fire neapolit~~in~~ pizza"



I search for...

- "~~the~~ best wood fired neapolitin pie"
- "best wood fire~~d~~ neapolitin pie"
- "best wood fire neapolitin ~~pie~~"
- "best wood fire neapolit~~in~~ pizza"
- "best wood fire neapolitan pizza"

I search for...

- "~~the~~ best wood fired neapolitin pie" (**stopwords**)
- "best wood fire~~d~~ neapolitin pie"
- "best wood fire neapolitin ~~pie~~"
- "best wood fire neapolit~~in~~ pizza"
- "best wood fire neapolitan pizza"

I search for...

- "~~the~~ best wood fired neapolitin pie" (stopwords)
- "best wood fire~~d~~ neapolitin pie" (stemming)
- "best wood fire neapolitin ~~pie~~"
- "best wood fire neapolit~~in~~ pizza"
- "best wood fire neapolitan pizza"

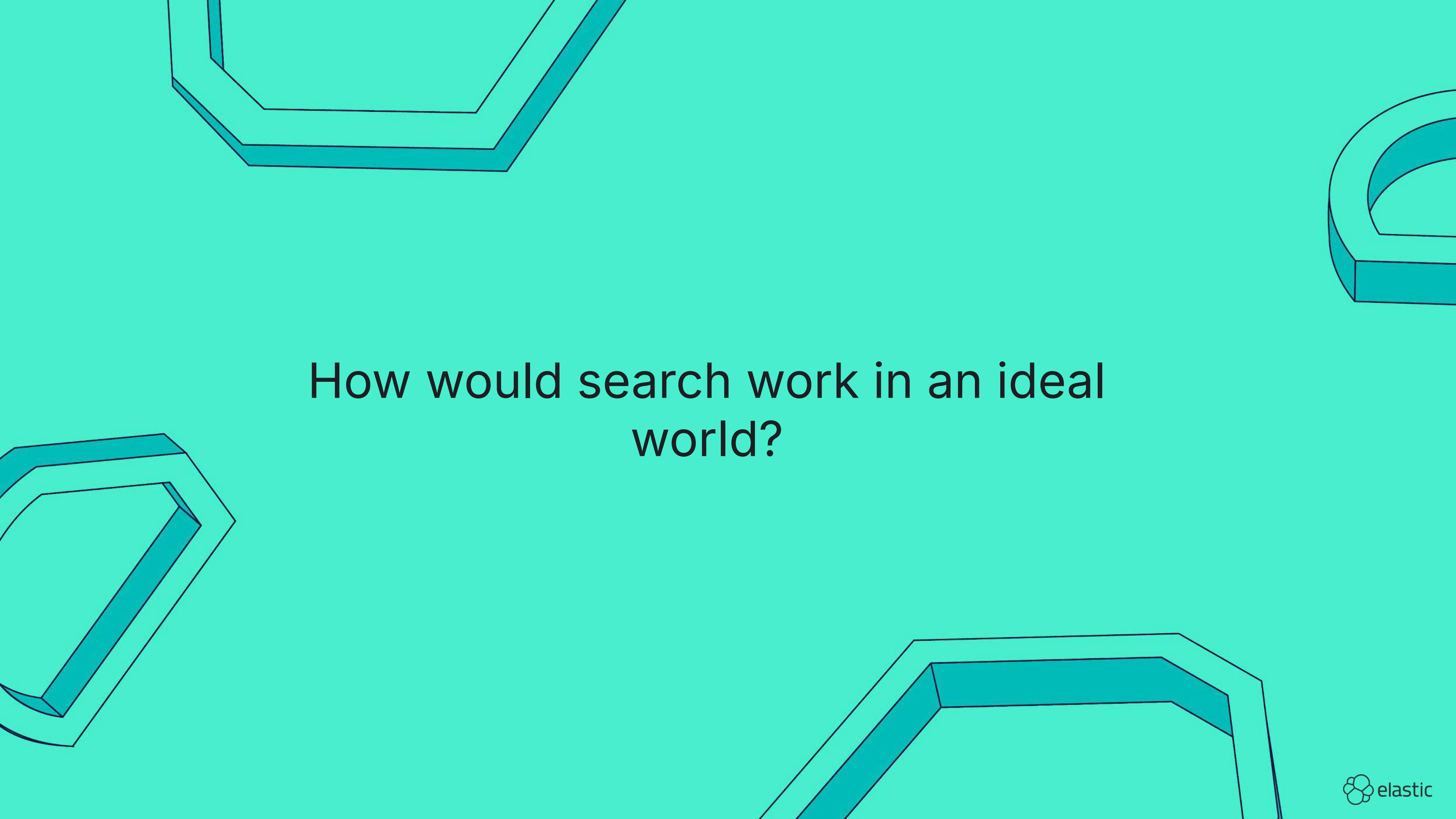
I search for...

- "~~the~~ best wood fired neapolitin pie" (stopwords)
- "best wood fire~~d~~ neapolitin pie" (stemming)
- "best wood fire neapolitin ~~pie~~" (synonyms)
- "best wood fire neapolit~~in~~ pizza"
- "best wood fire neapolitan pizza"

I search for...

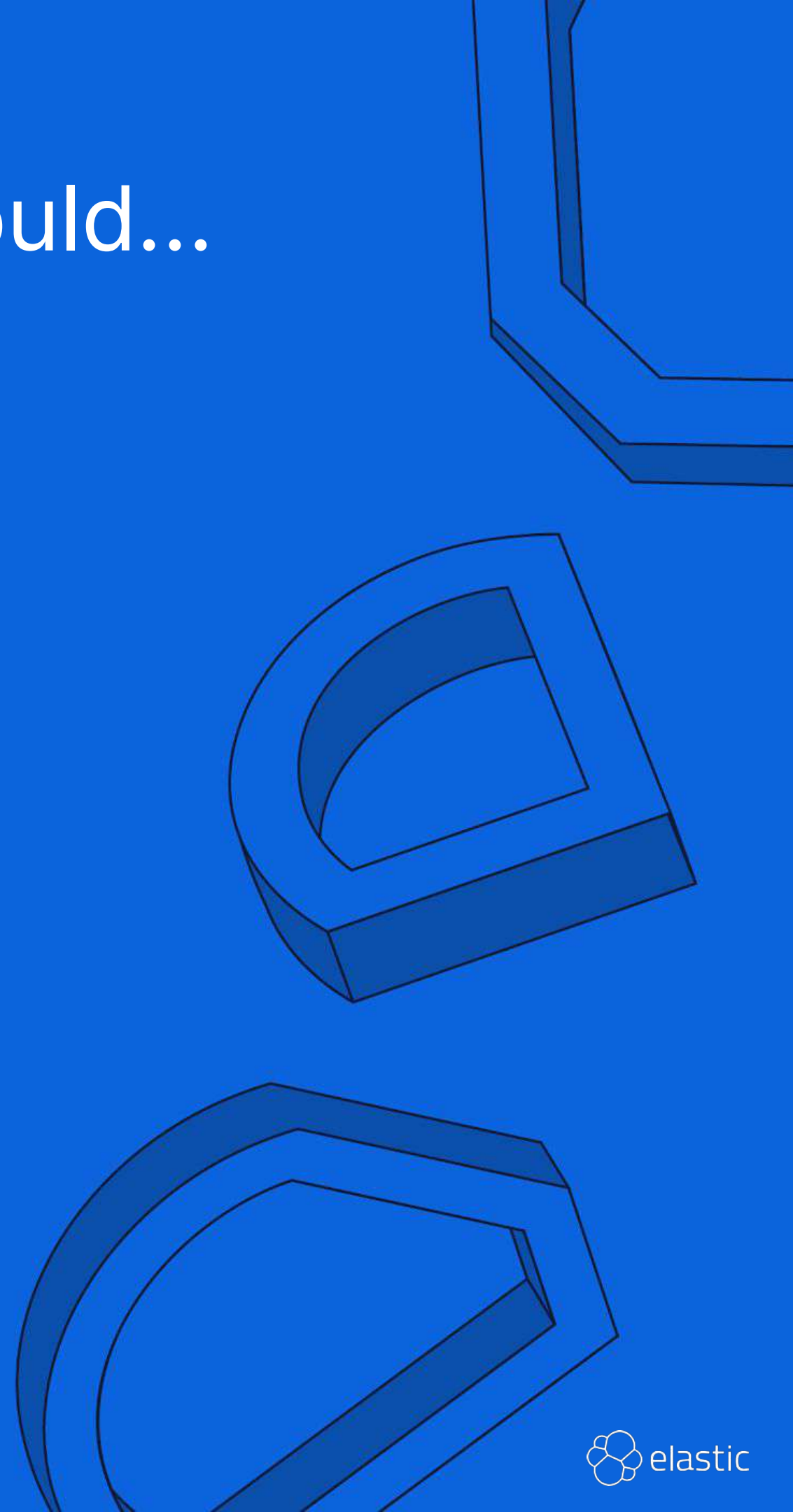
- "~~the~~ best wood fired neapolitin pie" (stopwords)
- "best wood fire~~d~~ neapolitin pie" (stemming)
- "best wood fire neapolitin ~~pie~~" (synonyms)
- "best wood fire neapolit~~in~~ pizza" (spell check)
- "best wood fire neapolitan pizza"

Level 9: Rerankers



How would search work in an ideal world?

Some person (let's say Reed Rancor) would...



Some person (let's say Reed Rancor) would...

- Retrieve all the relevant documents

Some person (let's say Reed Rancor) would...

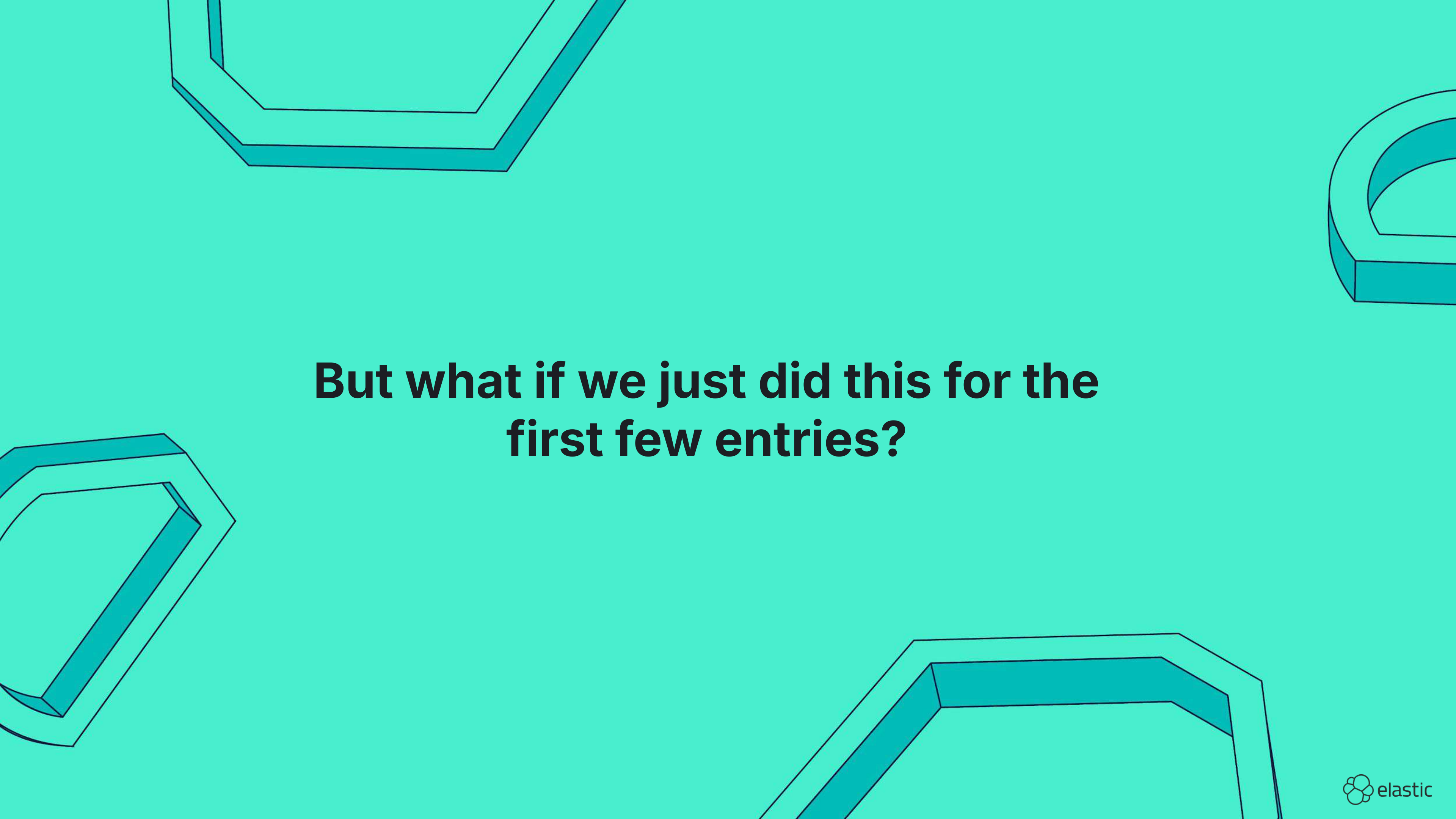
- Retrieve all the relevant documents
- Read through each one

Some person (let's say Reed Rancor) would...

- Retrieve all the relevant documents
- Read through each one
- Rank them all individually by relevance

The background features several abstract, 3D-style geometric shapes in teal and light blue. These shapes are composed of multiple parallel lines, creating a sense of depth and volume. They are arranged in a way that suggests a complex, interconnected structure, possibly representing a network or a data flow. The shapes are scattered across the frame, with some appearing more prominent than others.

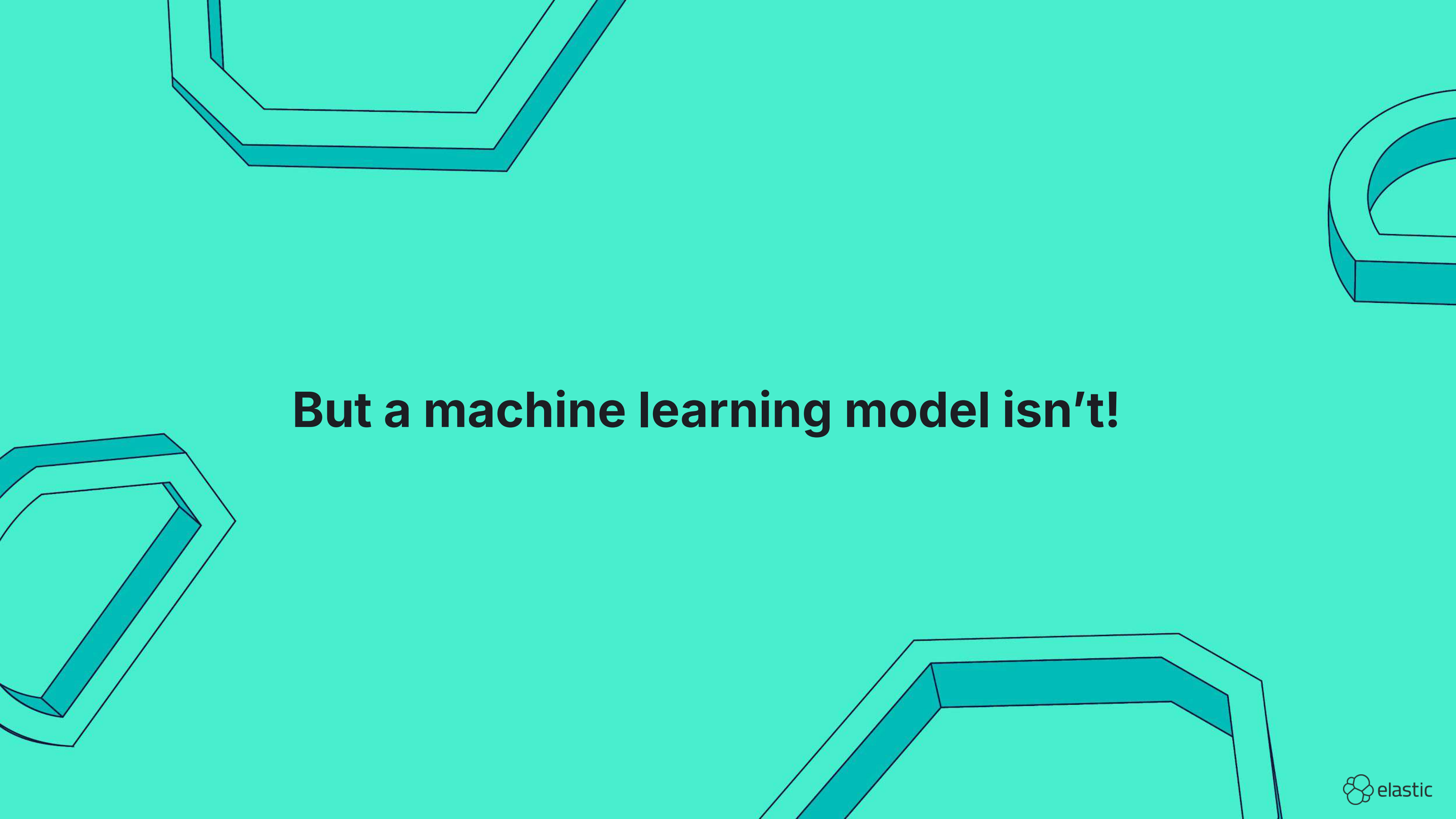
This is obviously not possible.

The background features several abstract, teal-colored geometric shapes. In the top left, there's a complex, multi-layered shape resembling a stylized 'L' or a corner. In the top right, a curved, shell-like shape is visible. On the left side, there's a shape that looks like a stylized 'C' or a partial circle. At the bottom, there are more angular, layered shapes. The overall aesthetic is modern and minimalist.

**But what if we just did this for the
first few entries?**

Reed is still too slow



The background features several abstract, teal-colored geometric shapes. In the top left, there's a complex, multi-layered shape resembling a stylized 'L' or a corner. In the top right, a curved, shell-like shape is visible. On the left side, there's a shape that looks like a stylized 'C' or a partial circle. At the bottom, there are more angular, layered shapes. The overall aesthetic is modern and minimalist.

But a machine learning model isn't!

“charred crust artichoke piza recipe”

“charred crust artichoke piza recipe”

Text Analysis

- Spell correct p-i-z-a to p-i-z-z-a
- Turn “charred” into its stem form, “char”

“charred crust artichoke piza recipe”

Text Analysis

- Spell correct p-i-z-a to p-i-z-z-a
- Turn “charred” into its stem form, “char”

Inverted Index

An inverted index grabs every recipe filed under “artichoke”

“charred crust artichoke piza recipe”

Text Analysis

- Spell correct p-i-z-a to p-i-z-z-a
- Turn “charred” into its stem form, “char”

Inverted Index

An inverted index grabs every recipe filed under “artichoke”

BM25

Assign scores to each recipe based on

- term frequency (TF)
- inverse document frequency (IDF)

“charred crust artichoke piza recipe”

Text Analysis

- Spell correct p-i-z-a to p-i-z-z-a
- Turn “charred” into its stem form, “char”

Inverted Index

An inverted index grabs every recipe filed under “artichoke”

BM25

Assign scores to each recipe based on

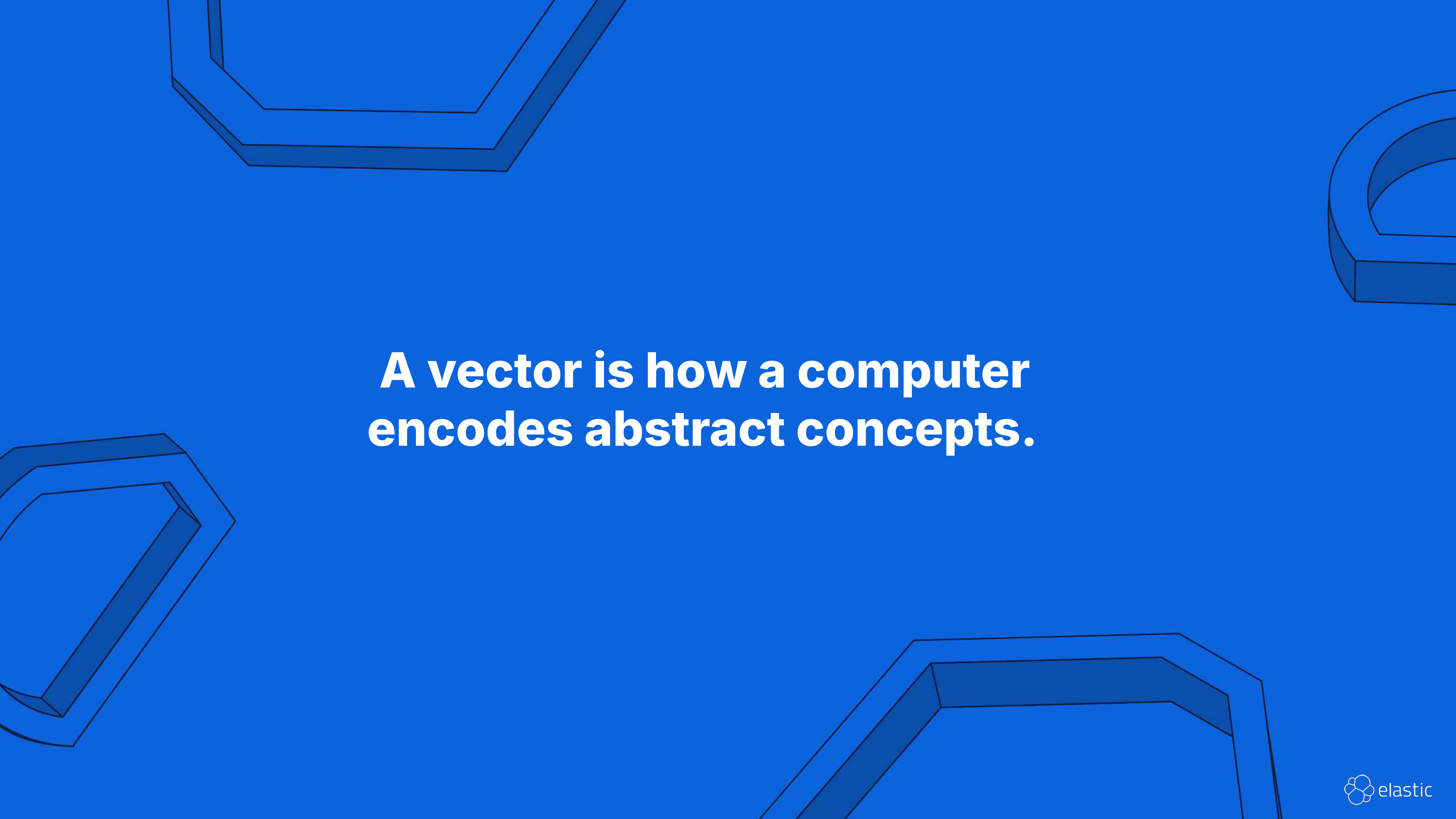
- term frequency (TF)
- inverse document frequency (IDF)

Reranker

Rerank the first few entries, since users are more likely to spend time on those

Any questions so far?

Level 10: Vectors

The background is a solid blue color. In the corners, there are abstract, 3D-style geometric shapes made of white lines. Top-left: A series of nested, slightly offset lines forming a corner. Top-right: A curved, 3D-style shape. Bottom-left: A more complex, multi-faceted geometric shape. Bottom-right: A series of nested, slightly offset lines forming a corner.

**A vector is how a computer
encodes abstract concepts.**

**How can we encode
Italian-American cuisine into
vectors?**

CHEESE

mozzarella sticks

stuffed shells

lasagna

fettuccine alfredo

pizza

vodka sauce

spaghetti & meatballs

garlic knots

focaccia

bruschetta

marinara

DOUGH

TOMATO

CHEESE

mozzarella sticks

stuffed shells

lasagna

fettuccine alfredo

pizza

vodka sauce

(0.05, 0.90, 0.05)

spaghetti & meatballs

garlic knots

focaccia

bruschetta

marinara

DOUGH

TOMATO

CHEESE

mozzarella sticks

stuffed shells

lasagna

fettuccine alfredo

pizza (0.05, 0.90, 0.05)

vodka sauce

spaghetti & meatballs

(0.05, 0.90, 0.05)

garlic knots

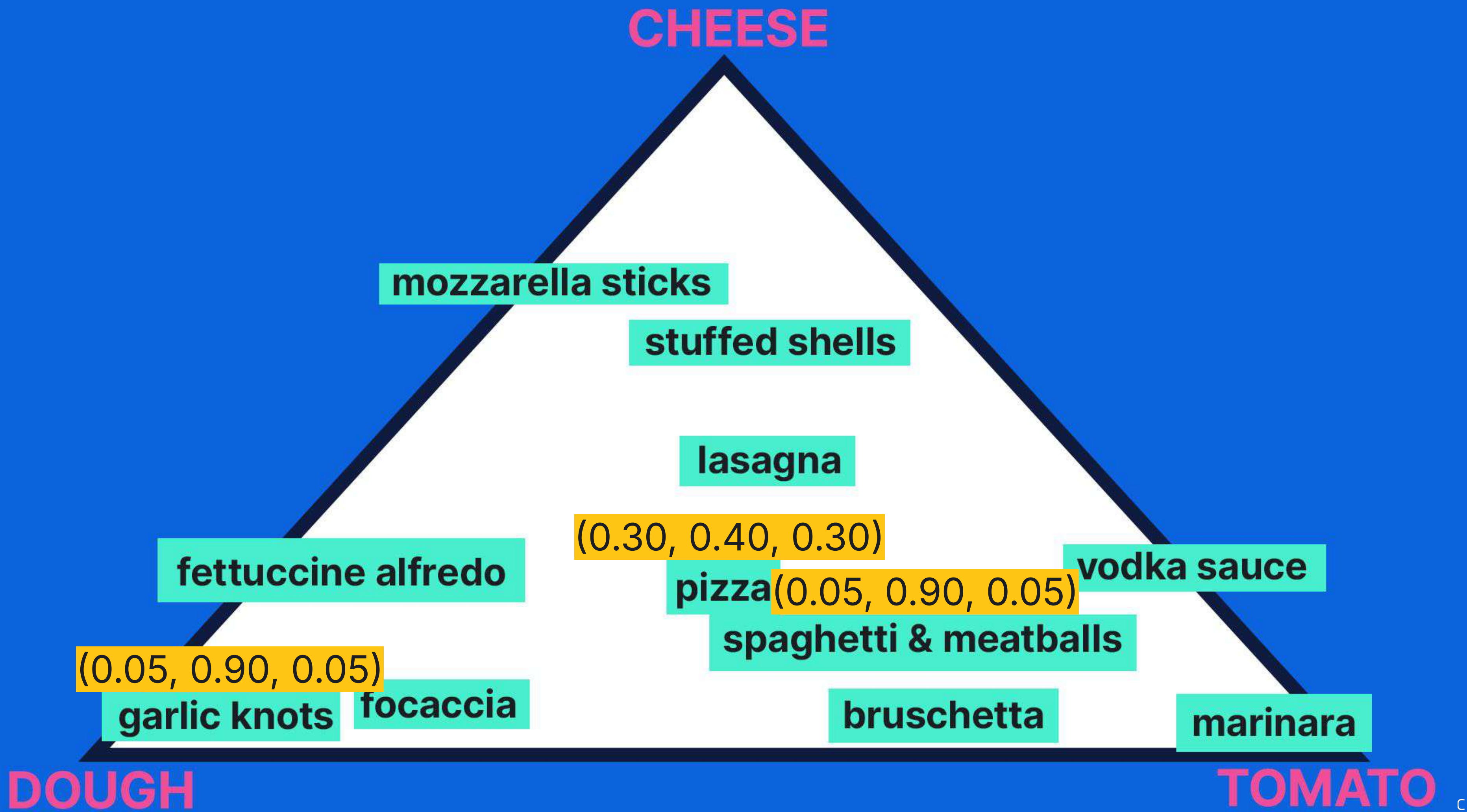
focaccia

bruschetta

marinara

DOUGH

TOMATO



CHEESE

(0.70, 0.25, 0.05)

mozzarella sticks

stuffed shells

lasagna

(0.30, 0.40, 0.30)

fettuccine alfredo

pizza (0.05, 0.90, 0.05)

vodka sauce

spaghetti & meatballs

(0.05, 0.90, 0.05)

garlic knots

focaccia

bruschetta

marinara

DOUGH

TOMATO

CHEESE

[0.821, 0.043, -0.112, 0.634, 0.299, -0.045, 0.518, 0.087, -0.203, 0.411...]

mozzarella sticks

stuffed shells

lasagna

[0.793, 0.512, 0.087, 0.198, -0.067, 0.341, 0.489, 0.215, -0.178, 0.367...]

fettuccine alfredo

vodka sauce

[0.845, -0.023, -0.098, 0.571, 0.412, -0.012, 0.502, 0.034, -0.245, 0.445...]

spaghetti & meatballs

[0.312, -0.287, 0.645, -0.134, 0.078, 0.189, 0.223, -0.512, 0.398, -0.067...]

garlic knots

focaccia

bruschetta

marinara

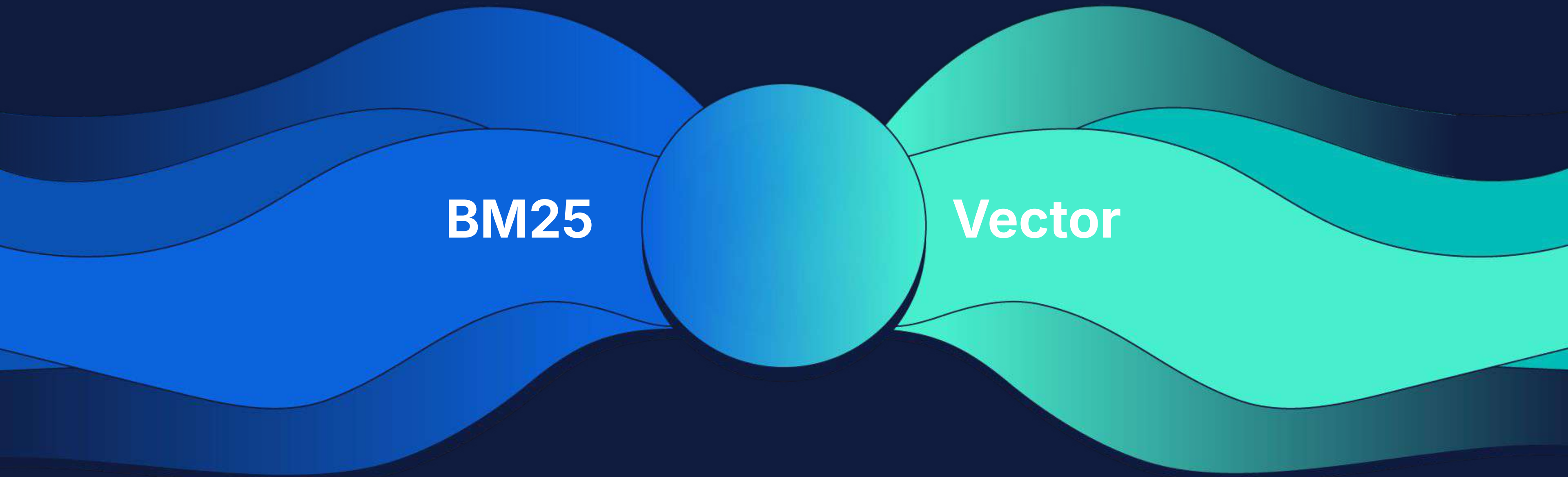
DOUGH

TOMATO

Level 11: Hybrid Search

Hybrid Search

The fusion of **BM25** and **vector-based search**



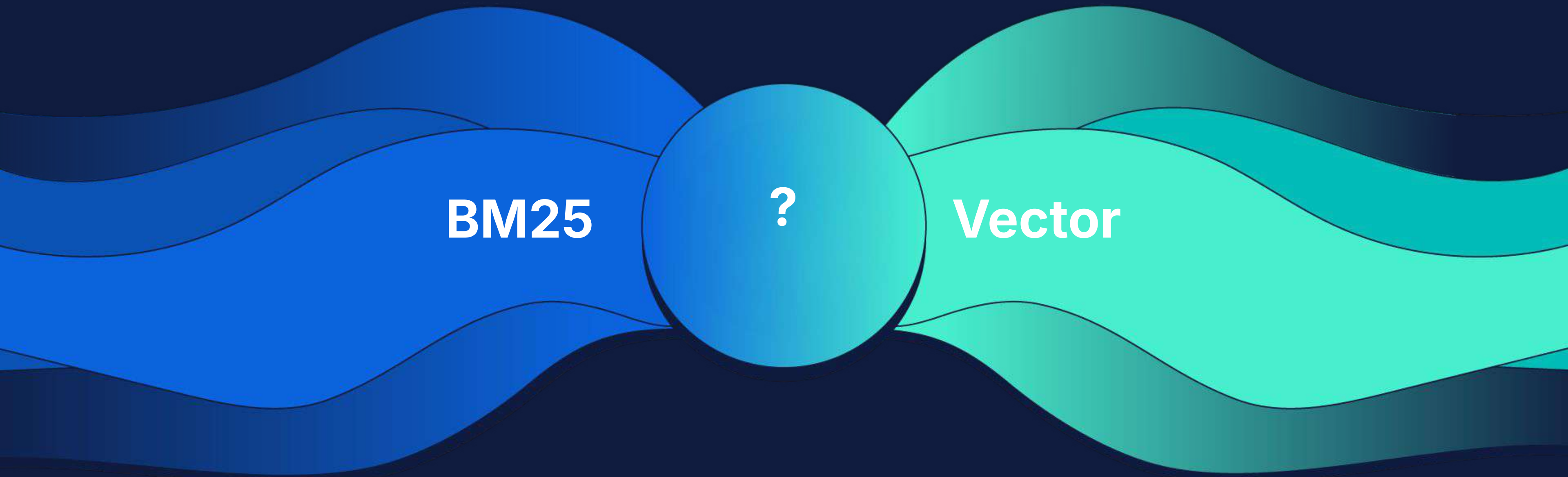
The diagram features a central light blue circle. To its left is a large, wavy blue shape containing the text 'BM25'. To its right is a large, wavy teal shape containing the text 'Vector'. The background is dark blue with horizontal wavy bands of varying shades of blue and teal.

BM25

Vector

Hybrid Search

The fusion of **BM25** and **vector-based search**



The diagram features a central light blue circle containing a white question mark. To the left of this circle is a large, wavy blue shape, and to the right is a large, wavy teal shape. The text 'BM25' is centered within the blue shape, and 'Vector' is centered within the teal shape. The background is a dark navy blue.

BM25

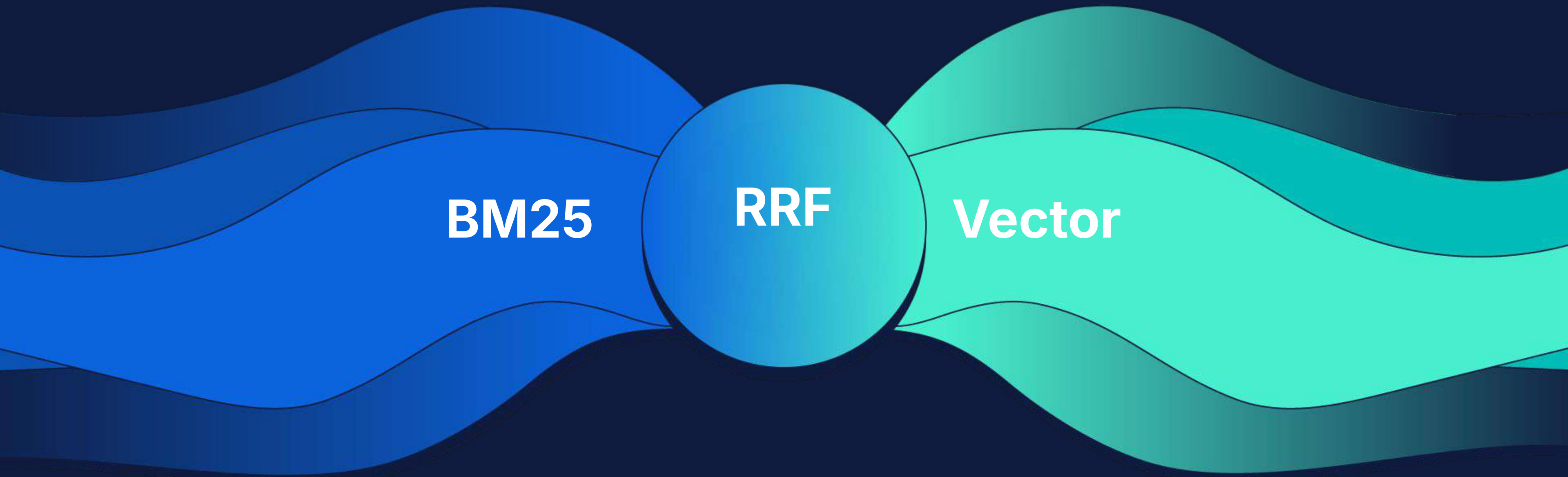
?

Vector

Reciprocal Rank Fusion (RRF)

Hybrid Search

The fusion of **BM25** and **vector-based search**



The diagram illustrates the fusion of BM25 and vector-based search into a hybrid search model. It features a central circle labeled 'RRF' (Reciprocal Rank Fusion) which is the result of combining the two search methods. To the left of the central circle is a large blue wavy shape labeled 'BM25', and to the right is a large teal wavy shape labeled 'Vector'. The central circle is a lighter shade of teal, representing the fusion of the two inputs.

BM25

RRF

Vector

“charred crust artichoke piza recipe”

Text Analysis

- Spell correct p-i-z-a to p-i-z-z-a
- Turn “charred” into its stem form, “char”

Inverted Index

An inverted index grabs every recipe filed under “artichoke”

BM25

Assign scores to each recipe based on

- term frequency (TF)
- inverse document frequency (IDF)

Reranker

Rerank the first few entries, since users are more likely to spend time on those

“charred crust artichoke piza recipe”

Text Analysis

- Spell correct p-i-z-a to p-i-z-z-a
- Turn “charred” into its stem form, “char”

Inverted Index

An inverted index grabs every recipe filed under “artichoke”

BM25 + Vector

Assign scores to each recipe based on

- term frequency (TF)
- inverse document frequency (IDF)
- vector proximity

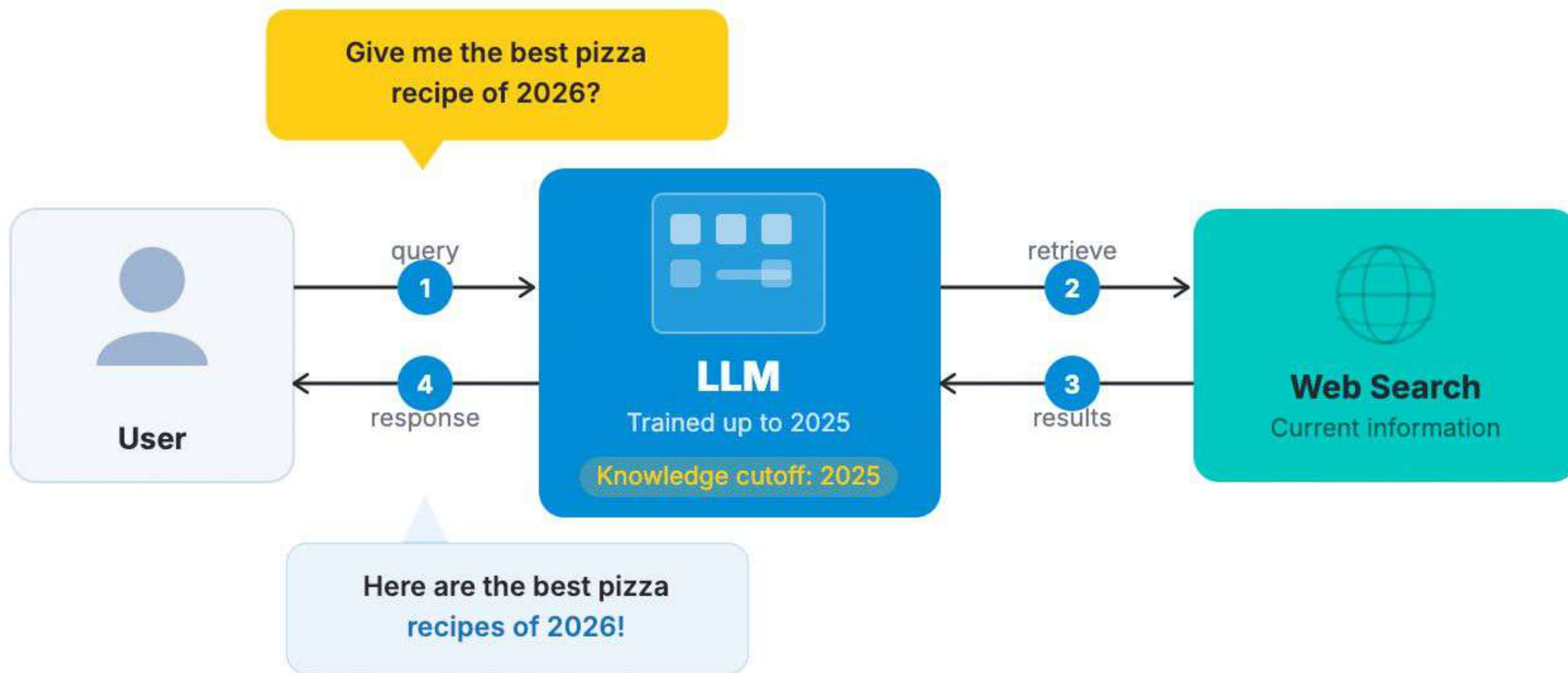
Reranker

Rerank the first few entries, since users are more likely to spend time on those

Level 12: RAG

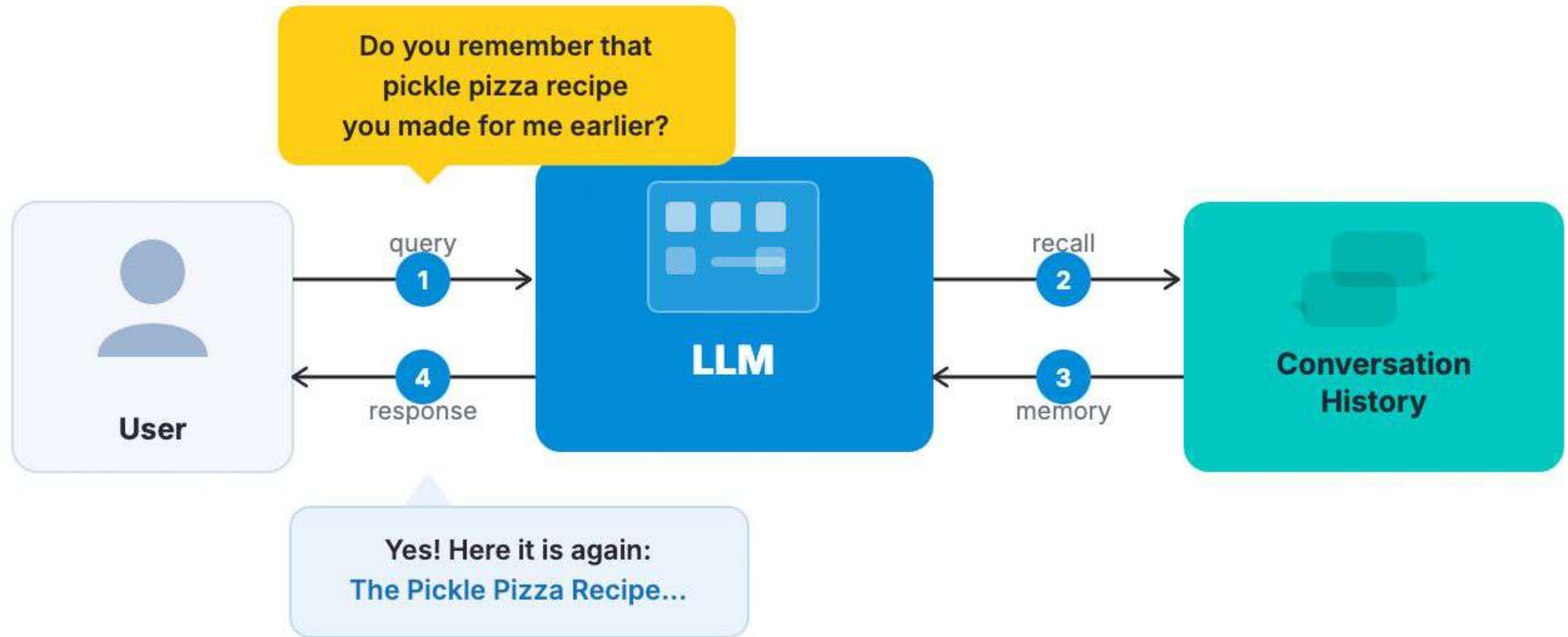
Retrieval Augmented Generation (RAG)

RAG



Level 13: Agentic Memory

Agentic Memory



Thank you! Any questions?

Let's connect on LinkedIn!

