

## Lab 2 - Chaotyczność generacji językowej

Do wykonania zadania zdecydowałem się użyć prostego modelu `meta-llama/Llama-3.2-3B`, dzięki temu cała generacja tekstu odbywać się będzie lokalnie, co zwiększy kontrole nad parametrami modelu.

### Ładowanie modelu

```
In [ ]: from transformers import AutoModelForCausalLM, AutoTokenizer
import torch

MODEL_ID = "meta-llama/Llama-3.2-3B"
DEVICE = "cuda"

def load(model_id: str = MODEL_ID):
    tok = AutoTokenizer.from_pretrained(model_id, use_fast=True)
    model = AutoModelForCausalLM.from_pretrained(model_id)

    model.eval()
    model.to(DEVICE)

    if tok.pad_token_id is None:
        tok.pad_token = tok.eos_token

    return model, tok

@torch.inference_mode()
def continue_text(
    model,
    tokenizer,
    prompt: str,
    *,
    max_new_tokens: int = 160,
    seed: int | None = None,
    stop: str | list[str] | None = None,
) -> str:
    # set seed
    if seed is not None:
        torch.manual_seed(seed)
        torch.mps.manual_seed(seed)

    # tokenize
    enc = tokenizer(prompt, return_tensors="pt", add_special_tokens=False)
    enc = {k: v.to(model.device) for k, v in enc.items()}

    # generation parameters
    gen_kwargs = dict(
        max_new_tokens=max_new_tokens,
        eos_token_id=tokenizer.eos_token_id,
        pad_token_id=tokenizer.pad_token_id,
        penalty_alpha=0.9,
        top_k=8
    )

    # generate completions
```

```

out = model.generate(**enc, **gen_kwargs)

# decode only the continuation
new_tokens = out[0, enc["input_ids"].shape[1]:]
text = tokenizer.decode(new_tokens, skip_special_tokens=True)

if stop:
    stops = [stop] if isinstance(stop, str) else list(stop)
    cut_at = min([text.find(s) for s in stops if s in text]) + [len(text)]
    text = text[:cut_at]

return text

model, tokenizer = load()
seed_text = (
    "On a rain-slick evening in Lisbon, the tram doors slid open and I st
)
print(continue_text(model, tokenizer, seed_text, seed=42))

```

Loading checkpoint shards: 0% | 0/2 [00:00<?, ?it/s]  
 "I'm not going to tell you what I think of you, because I don't want to hurt you." The stranger was a woman, and she was speaking to a man.  
 "Don't worry, I don't care," he replied.  
 I had a seat next to them, and I was tempted to ask if they were together, but I didn't. I sat in silence for a few moments, and then the man turned to her and said, "I'm going to tell you what I think of you, because I don't want you to think I don't care."  
 She looked at him, and then she looked at me, and then she looked back at him. I could see the hurt in her eyes, but she didn't say anything.  
 He turned to me and

## Generowanie dopełnień

Mając załadowany model zdolny do dopełniania tekstu, wygenerowałem dwa seedy które następnie uzupełniłem za pomocą modelu. Ustawienie opcji `do_sample = False` gwarantuje zachlanny wybór tokenu przez model, bez dodawania szumu.

```

In [13]: # seeds
SHORT = lambda season: (
    f"On a {season} evening by the harbor, the city lights flickered like
    \"and a letter in my pocket felt heavier than paper.\""
)

MEDIUM = lambda season: (
    f"On a {season} evening by the harbor, the city lights flickered like
    \"and a letter in my pocket felt heavier than paper. Somewhere out on
    \"horn sounded once, then faded into the hush between waves. I unfold
    \"at the letter's edge and knew, before reading, that it would redraw
    \""
)

LONG = lambda season: (
    f"On a {season} evening by the harbor, the city lights flickered like
    \"and a letter in my pocket felt heavier than paper. Somewhere out on
    \"horn sounded once, then faded into the hush between waves. I unfold
    \"at the letter's edge and knew, before reading, that it would redraw
    \" I read the first line, and the wind seemed to lean closer."
    " Names I hadn't spoken in years stepped out of the ink like silhouet
    " The letter asked for forgiveness, but what it offered was a compass
    " By the time I folded it shut, the tide had risen to meet my shoes."
)

```

```
)\n\nseasons = ["fall", "summer"]\nsizes = ["short", "medium", "long"]\nprompts = [SHORT, MEDIUM, LONG]\n\ncompletions = {\n    size: {season: "" for season in seasons}\n    for size in ["short", "medium", "long"]\n}\n\nfor size, prompt in zip(sizes, prompts):\n    for season in seasons:\n        to_complete = prompt(season)\n        print(to_complete)\n        completion = continue_text(model, tokenizer, to_complete, max_new)\n        completions[size][season] = completion\n\n        print(f"Size: {size}, season: {season}, completion: {completion}")
```

On a fall evening by the harbor, the city lights flickered like patient beacons, and a letter in my pocket felt heavier than paper.

Size: short, season: fall, completion: I was going to ask her to marry me. The idea had come to me while I was driving home from the hospital, where I'd seen a young woman die of a drug overdose. She'd been only twenty-two, and I'd felt a strange, almost physical connection to her, as if she were a part of me. I'd been thinking about her when I'd come to a stoplight and seen a woman on the sidewalk. She was young, with long, dark hair and a face that was both pretty and sad. I'd thought about her for a long time, and then I'd gone to a jewelry store and bought a ring. It was a simple gold band, and I'd felt a sense of calm and purpose when I'd placed it on her finger. Now, as I walked along the pier, I was nervous and excited, and I hoped that she would say yes.

I found her sitting on a bench, looking out at the water. She turned to me with a smile, and I handed her the letter. She read it, and then she looked up at me with tears in her eyes.

"I love you," she said. "Yes, I'll marry you."

I felt a surge of joy and relief, and I hugged her tightly. I knew that I'd made the right decision, and that we were going to be together for a long time.

I was sitting in a coffee shop, reading a book, when I heard a voice behind me

On a summer evening by the harbor, the city lights flickered like patient beacons, and a letter in my pocket felt heavier than paper.

Size: short, season: summer, completion: I was going home.

I walked slowly, my eyes on the ground, and the world around me seemed to shift into a dream. I could almost believe I was walking through a field of daisies, with the sun on my back and a gentle breeze blowing my hair. The only thing that kept me grounded was the weight of the letter in my pocket. It was a reminder that I was not just walking through a field of daisies; I was walking home.

I was almost at the end of my journey when I saw the sign: "Welcome Home." It was a small sign, but it meant everything to me. It was like a beacon, guiding me towards my destination. I couldn't help but smile as I read the words, and I knew that I was almost home.

As I continued walking, I could feel the weight of the letter in my pocket lessening. I was almost home, and I knew that my family would be waiting for me with open arms. I could almost feel their hugs, and I was excited to see them again.

I continued walking, and the sun began to set. The sky was a beautiful blend of pink and orange, and the stars began to appear. It was a perfect night for a homecoming, and I couldn't wait to see my family.

As I approached the house, I could hear the sound of laughter and music coming from inside. I knew that my family was waiting for me, and I couldn't wait to

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Size: medium, season: fall, completion: I was not alone.

I had been in New York City only a few days when I first met him. He was tall, and his eyes were brown, and his hair was black. He was not like anyone I'd known before. I didn't know what to do with him, but I liked him. I liked the way he looked at me. I liked the way he said my name. I liked the way he smelled.

I was in my junior year of college, and I was living with a friend, who had a boyfriend, who lived in a studio apartment in Greenwich Village. The apartment was small and crowded. It was also cheap, and we could afford it. I was a poor student, and my friend was a poor student, and we had no money

y for rent. We had no money for food, and we were both hungry. We had no money for clothes, and we were both cold. We had no money for books, and we were both behind in our classes. We had no money for anything. We had no money for love.

I met him on the subway. I was coming home from work, and he was coming home from school. He was wearing a black leather jacket, and he was carrying a black leather bag, and he was carrying a black leather briefcase, and he was carrying a black leather satchel, and he was carrying a black leather backpack, and he was carrying a black leather messenger bag, and he was carrying a

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Size: medium, season: summer, completion: I was not alone in this, for the letters of my childhood, and those of my adolescence, and even the few I'd written, had already done so. The letters I'd written to my mother, and those I'd received in response, had changed me, as if they'd been my first and last words. I was not alone in this, for the letters of my childhood, and those of my adolescence, and even the few I'd written, had already done so. I was not alone in this, for the letters of my childhood, and those of my adolescence, and even the few I'd written, had already done so. The letter was from my mother. I knew that before I opened it. The postmark was from New York City, where she lived, and the envelope was thick, as if it had been mailed in a padded envelope. I'd written to her only once since I'd left home, and then only to let her know that I was all right. I'd written to her only once since I'd left home, and then only to let her

know that I was all right. She'd written back immediately, and in a few words had told me that she was glad to hear from me, and that she hoped I was doing well. She'd written back immediately, and in a few words had told me that she was glad to hear from me, and that she hoped I was doing well.

I'd written to her only once since

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Size: long, season: fall, completion: I walked home alone, with the wind in my hair and the letter in my pocket.

On a summer evening by the harbor, the city lights flickered like patient

beacons, and a letter in my pocket felt heavier than paper. Somewhere out on the water, a horn sounded once, then faded into the hush between waves. I unfolded the crease at the letter's edge and knew, before reading, that it would redraw the map of my small life. I read the first line, and the wind seemed to lean closer. Names I hadn't spoken in years stepped out of the ink like silhouettes on the pier. The letter asked for forgiveness, but what it offered was a compass. By the time I folded it shut, the tide had risen to meet my shoes.

Size: long, season: summer, completion: I walked home alone, and when I reached my apartment, I found that the letter was still in my pocket. I had left it there.

I was born in a small town on the coast of Maine, and when I was a child, my father took me to the ocean every chance he got. We'd drive the long way, through the woods, and then, once we reached the beach, we'd walk until the waves were too rough to stand. I'd stand, anyway, and watch the water rise, and my father would tell me stories about the sea. He told me about the great ships that sailed it, and the men who sailed them. He told me about the sailors who were lost, and the sailors who were found. He told me about the sailors who were lost, and the sailors who were found. He told me about the sailors who were lost, and the sailors who were found.

I grew up to be a sailor, too. I sailed the ocean, and the rivers, and the lakes. I sailed the world, and the stars. I sailed through the night, and the day. I sailed the sea, and the sky, and the wind.

And then I sailed home.

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## Analiza wygenerowanych dopełnień

In [14]:

```
import math, re
import matplotlib.pyplot as plt

def tokenize_words(text: str):
    return re.findall(r"\b\w+\b", text.lower())

def levenshtein_prefix_series(a_words, b_words):
    K = min(len(a_words), len(b_words))
    a = a_words[:K]
    b = b_words[:K]
    D = [[0]*(K+1) for _ in range(K+1)]
    for i in range(1, K+1):
        D[i][0] = i
    for j in range(1, K+1):
        D[0][j] = j
    for i in range(1, K+1):
        ai = a[i-1]
        for j in range(1, K+1):
            cost = 0 if ai == b[j-1] else 1
            D[i][j] = min(D[i-1][j] + 1, D[i][j-1] + 1, D[i-1][j-1] + cost)
    return [D[k][k] for k in range(1, K+1)]

def effective_lyapunov(d_series):
    if not d_series:
        return []
    base = d_series[0] + 1
    lam = [math.log((d_series[k-1] + 1) / base) / k for k in range(1, len(d_series))]
    return lam
```

```

def normalized_divergence(d_series):
    return [d / (k+1) for k, d in enumerate(d_series)]


def plot_metrics_for_size(size: str, completions: dict, seasons: list[str]):
    a_text = completions[size][seasons[0]]
    b_text = completions[size][seasons[1]]

    a_words = tokenize_words(a_text)
    b_words = tokenize_words(b_text)
    d = levenshtein_prefix_series(a_words, b_words)

    ks = list(range(1, len(d)+1))
    delta = [d_k / k for k, d_k in enumerate(d, start=1)]
    lam = [math.log(d_k + 1) / k for k, d_k in enumerate(d, start=1)]
    lam_rel = [math.log(d_k / k + 1) / k for k, d_k in enumerate(d, start=1)]

    axs[0].plot(ks, delta, label=size)
    axs[0].set_xlabel("k (words)");
    axs[0].set_ylabel("value d(k)/k")
    axs[0].grid(True, linestyle="--", linewidth=0.5)

    axs[1].plot(ks, d, label=size)
    axs[1].set_xlabel("k (words)");
    axs[1].set_ylabel("value d(k)")
    axs[1].grid(True, linestyle="--", linewidth=0.5)

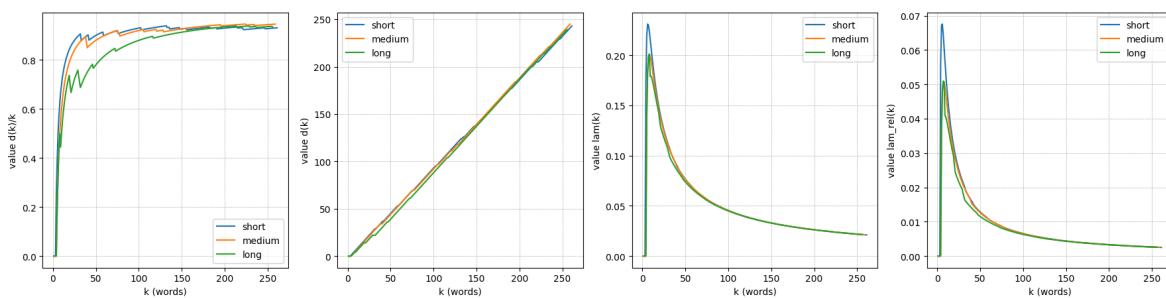
    axs[2].plot(ks, lam, label=size)
    axs[2].set_xlabel("k (words)");
    axs[2].set_ylabel("value lam(k)")
    axs[2].grid(True, linestyle="--", linewidth=0.5)

    axs[3].plot(ks, lam_rel, label=size)
    axs[3].set_xlabel("k (words)");
    axs[3].set_ylabel("value lam_rel(k)")
    axs[3].grid(True, linestyle="--", linewidth=0.5)

fig, axs = plt.subplots(1, 4, figsize=(22, 5))
for size in sizes:
    plot_metrics_for_size(size, completions, seasons, axs)

for ax in axs:
    ax.legend()
plt.show()

```



## Podsumowanie

Jak widzimy, bardzo mała zmiana promptu (zmiana pory roku z `fall` na `summer`) bardzo wpływa na generowany tekst przez model. Warto zauwazyć, że teksty

generowałem w sposób deterministyczny, czyli model zawsze zwracał token o największym prawdopodobieństwie. Na wykresie drugim, widzimy, że dokończenia rozjechały się praktycznie od razu (tylko pierwsze  $< 5$  słów jest podobnych) oraz rosną praktycznie liniowo, co oznacza, że słowa generowane dla podobnych promptów są całkowicie różne. Długość promptu, pomimo zmniejszenia procentu perturbacji w kontekście całego tekstu wejściowego, wcale nie stabilizuje trajektorii generowanego tekstu. Prawdopodobnie wynika to z