```
# Uncomment for colab
#
!pip install -q torchdata==0.3.0 torchtext==0.12 spacy==3.2 altair GPUtil
!python -m spacy download de_core_news_sm
!python -m spacy download en_core_web_sm
```

```
Requirement already satisfied: pathy>=0.3.5 in /usr/local/lib/python3.9/dist-packages (from spacy<3.3.0,>=3.2.0->de-core-news
Requirement already satisfied: smart-open<7.0.0,>=5.2.1 in /usr/local/lib/python3.9/dist-packages (from pathy>=0.3.5->spacy<3
Requirement already satisfied: typing-extensions>=3.7.4.3 in /usr/local/lib/python3.9/dist-packages (from pydantic!=1.8,!=1.8
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.9/dist-packages (from requests<3.0.0,>=2.13.0->sp
Requirement already satisfied: charset-normalizer~=2.0.0 in /usr/local/lib/python3.9/dist-packages (from requests<3.0.0,>=2.1
Requirement already satisfied: urllib3<1.27,>=1.21.1 in /usr/local/lib/python3.9/dist-packages (from requests<3.0.0,>=2.13.0-
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.9/dist-packages (from requests<3.0.0,>=2.13.0->spacy<3.
Requirement already satisfied: click<9.0.0,>=7.1.1 in /usr/local/lib/python3.9/dist-packages (from typer<0.5.0,>=0.3.0->spacy
Requirement already satisfied: MarkupSafe>=2.0 in /usr/local/lib/python3.9/dist-packages (from jinja2->spacy<3.3.0,>=3.2.0->d
Installing collected packages: de-core-news-sm
Successfully installed de-core-news-sm-3.2.0
✔ Download and installation successful
You can now load the package via spacy.load('de_core_news_sm')
2023-04-20 21:26:38.364299: I tensorflow/core/platform/cpu_feature_guard.cc:182] This TensorFlow binary is optimized to use a
To enable the following instructions: AVX2 AVX512F FMA, in other operations, rebuild TensorFlow with the appropriate compiler
2023-04-20 21:26:39.361329: W tensorflow/compiler/tf2tensorrt/utils/py_utils.cc:38] TF-TRT Warning: Could not find TensorRT
DEPRECATION: https://github.com/explosion/spacy-models/releases/download/en_core_web_sm-3.2.0/en_core_web_sm-3.2.0-py3-none-a
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Collecting en-core-web-sm==3.2.0
  Downloading https://github.com/explosion/spacy-models/releases/download/en_core_web_sm-3.2.0/en_core_web_sm-3.2.0-py3-none-
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 13.9/13.9 MB 37.6 MB/s eta 0:00:00
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Requirement already satisfied: srsly<3.0.0,>=2.4.1 in /usr/local/lib/python3.9/dist-packages (from spacy<3.3.0,>=3.2.0->en-co
Requirement already satisfied: murmurhash<1.1.0,>=0.28.0 in /usr/local/lib/python3.9/dist-packages (from spacy<3.3.0,>=3.2.0-
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Requirement already satisfied: cymem<2.1.0,>=2.0.2 in /usr/local/lib/python3.9/dist-packages (from spacy<3.3.0,>=3.2.0->en-co
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Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.9/dist-packages (from requests<3.0.0,>=2.13.0->spacy<3.
Requirement already satisfied: click<9.0.0,>=7.1.1 in /usr/local/lib/python3.9/dist-packages (from typer<0.5.0,>=0.3.0->spacy
Requirement already satisfied: MarkupSafe>=2.0 in /usr/local/lib/python3.9/dist-packages (from jinja2->spacy<3.3.0,>=3.2.0->e
Installing collected packages: en-core-web-sm
  Attempting uninstall: en-core-web-sm
    Found existing installation: en-core-web-sm 3.5.0
    Uninstalling en-core-web-sm-3.5.0:
      Successfully uninstalled en-core-web-sm-3.5.0
Successfully installed en-core-web-sm-3.2.0
✔ Download and installation successful
You can now load the package via spacy.load('en_core_web_sm')
```
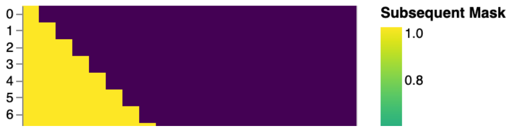
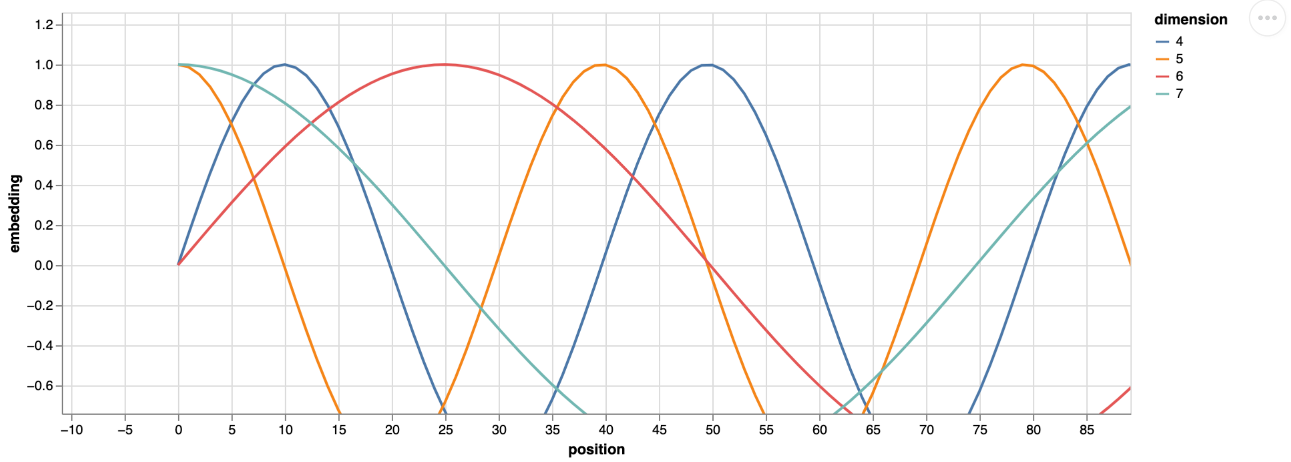

```
import os
from os.path import exists
import torch
import torch.nn as nn
from torch.nn.functional import log_softmax, pad
import math
import copy
import time
from torch.optim.lr_scheduler import LambdaLR
import pandas as pd
import altair as alt
from torchtext.data.functional import to_map_style_dataset
from torch.utils.data import DataLoader
from torchtext.vocab import build_vocab_from_iterator
import torchtext.datasets as datasets
import spacy
import GPUtil
import warnings
from torch.utils.data.distributed import DistributedSampler
import torch.distributed as dist
import torch.multiprocessing as mp
from torch.nn.parallel import DistributedDataParallel as DDP


# Set to False to skip notebook execution (e.g. for debugging)
warnings.filterwarnings("ignore")
RUN_EXAMPLES = True



# Some convenience helper functions used throughout the notebook


def is_interactive_notebook():
    return __name__ == "__main__"


def show_example(fn, args=[]):
    if __name__ == "__main__" and RUN_EXAMPLES:
        return fn(*args)


def execute_example(fn, args=[]):
    if __name__ == "__main__" and RUN_EXAMPLES:
        fn(*args)


class DummyOptimizer(torch.optim.Optimizer):
    def __init__(self):
        self.param_groups = [{"lr": 0}]
        None

    def step(self):
        None

    def zero_grad(self, set_to_none=False):
        None


class DummyScheduler:
    def step(self):
        None


class EncoderDecoder(nn.Module):
    """
    A standard Encoder-Decoder architecture. Base for this and many
    other models.
    """

    def __init__(self, encoder, decoder, src_embed, tgt_embed, generator):
        super(EncoderDecoder, self).__init__()
        self.encoder = encoder
        self.decoder = decoder
        self.src_embed = src_embed
        self.tgt_embed = tgt_embed
        self.generator = generator

    def forward(self, src, tgt, src_mask, tgt_mask):
        "Take in and process masked src and target sequences."
        return self.decode(self.encode(src, src_mask), src_mask, tgt, tgt_mask)

    def encode(self, src, src_mask):
        return self.encoder(self.src_embed(src), src_mask)

    def decode(self, memory, src_mask, tgt, tgt_mask):
        return self.decoder(self.tgt_embed(tgt), memory, src_mask, tgt_mask)


class Generator(nn.Module):
    "Define standard linear + softmax generation step."

    def __init__(self, d_model, vocab):
        super(Generator, self).__init__()
        self.proj = nn.Linear(d_model, vocab)

    def forward(self, x):
        return log_softmax(self.proj(x), dim=-1)


def clones(module, N):
    "Produce N identical layers."
    return nn.ModuleList([copy.deepcopy(module) for _ in range(N)])


class Encoder(nn.Module):
    "Core encoder is a stack of N layers"

    def __init__(self, layer, N):
        super(Encoder, self).__init__()
        self.layers = clones(layer, N)
        self.norm = LayerNorm(layer.size)

    def forward(self, x, mask):
        "Pass the input (and mask) through each layer in turn."
        for layer in self.layers:
            x = layer(x, mask)
        return self.norm(x)


class LayerNorm(nn.Module):
    "Construct a layernorm module (See citation for details)."

    def __init__(self, features, eps=1e-6):
        super(LayerNorm, self).__init__()
        self.a_2 = nn.Parameter(torch.ones(features))
        self.b_2 = nn.Parameter(torch.zeros(features))
        self.eps = eps

    def forward(self, x):
        mean = x.mean(-1, keepdim=True)
        std = x.std(-1, keepdim=True)
        return self.a_2 * (x - mean) / (std + self.eps) + self.b_2


class SublayerConnection(nn.Module):
    """
    A residual connection followed by a layer norm.
    Note for code simplicity the norm is first as opposed to last.
    """

    def __init__(self, size, dropout):
        super(SublayerConnection, self).__init__()
        self.norm = LayerNorm(size)
        self.dropout = nn.Dropout(dropout)

    def forward(self, x, sublayer):
        "Apply residual connection to any sublayer with the same size."
        return x + self.dropout(sublayer(self.norm(x)))


class EncoderLayer(nn.Module):
    "Encoder is made up of self-attn and feed forward (defined below)"

    def __init__(self, size, self_attn, feed_forward, dropout):
        super(EncoderLayer, self).__init__()
        self.self_attn = self_attn
        self.feed_forward = feed_forward
        self.sublayer = clones(SublayerConnection(size, dropout), 2)
        self.size = size

    def forward(self, x, mask):
        "Follow Figure 1 (left) for connections."
        x = self.sublayer[0](x, lambda x: self.self_attn(x, x, x, mask))
        return self.sublayer[1](x, self.feed_forward)


class Decoder(nn.Module):
    "Generic N layer decoder with masking."

    def __init__(self, layer, N):
        super(Decoder, self).__init__()
        self.layers = clones(layer, N)
        self.norm = LayerNorm(layer.size)

    def forward(self, x, memory, src_mask, tgt_mask):
        for layer in self.layers:
            x = layer(x, memory, src_mask, tgt_mask)
        return self.norm(x)


class DecoderLayer(nn.Module):
    "Decoder is made of self-attn, src-attn, and feed forward (defined below)"

    def __init__(self, size, self_attn, src_attn, feed_forward, dropout):
        super(DecoderLayer, self).__init__()
        self.size = size
        self.self_attn = self_attn
        self.src_attn = src_attn
        self.feed_forward = feed_forward
        self.sublayer = clones(SublayerConnection(size, dropout), 3)

    def forward(self, x, memory, src_mask, tgt_mask):
        "Follow Figure 1 (right) for connections."
        m = memory
        x = self.sublayer[0](x, lambda x: self.self_attn(x, x, x, tgt_mask))
        x = self.sublayer[1](x, lambda x: self.src_attn(x, m, m, src_mask))
        return self.sublayer[2](x, self.feed_forward)


def subsequent_mask(size):
    "Mask out subsequent positions."
    attn_shape = (1, size, size)
    subsequent_mask = torch.triu(torch.ones(attn_shape), diagonal=1).type(
        torch.uint8
    )
    return subsequent_mask == 0


def example_mask():
    LS_data = pd.concat(
        [
            pd.DataFrame(
                {
                    "Subsequent Mask": subsequent_mask(20)[0][x, y].flatten(),
                    "Window": y,
                    "Masking": x,
                }
            )
            for y in range(20)
            for x in range(20)
        ]
    )

    return (
        alt.Chart(LS_data)
        .mark_rect()
        .properties(height=250, width=250)
        .encode(
            alt.X("Window:O"),
            alt.Y("Masking:O"),
            alt.Color("Subsequent Mask:Q", scale=alt.Scale(scheme="viridis")),
        )
        .interactive()
    )


show_example(example_mask)
```



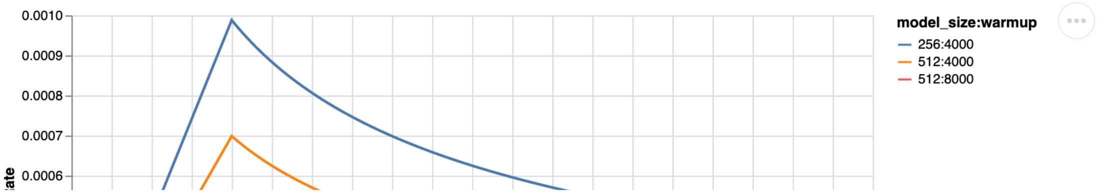
```
def attention(query, key, value, mask=None, dropout=None):
    "Compute 'Scaled Dot Product Attention'"
    d_k = query.size(-1)
    scores = torch.matmul(query, key.transpose(-2, -1)) / math.sqrt(d_k)
    if mask is not None:
        scores = scores.masked_fill(mask == 0, -1e9)
    p_attn = scores.softmax(dim=-1)
    if dropout is not None:
        p_attn = dropout(p_attn)
    return torch.matmul(p_attn, value), p_attn


class MultiHeadedAttention(nn.Module):
    def __init__(self, h, d_model, dropout=0.1):
        "Take in model size and number of heads."
        super(MultiHeadedAttention, self).__init__()
        assert d_model % h == 0
        # We assume d_v always equals d_k
        self.d_k = d_model // h
        self.h = h
        self.linears = clones(nn.Linear(d_model, d_model), 4)
        self.attn = None
        self.dropout = nn.Dropout(p=dropout)

    def forward(self, query, key, value, mask=None):
        "Implements Figure 2"
        if mask is not None:
            # Same mask applied to all h heads.
            mask = mask.unsqueeze(1)
        nbatches = query.size(0)

        # 1) Do all the linear projections in batch from d_model => h x d_k
        query, key, value = [
            lin(x).view(nbatches, -1, self.h, self.d_k).transpose(1, 2)
            for lin, x in zip(self.linears, (query, key, value))
        ]

        # 2) Apply attention on all the projected vectors in batch.
        x, self.attn = attention(
            query, key, value, mask=mask, dropout=self.dropout
        )

        # 3) "Concat" using a view and apply a final linear.
        x = (
            x.transpose(1, 2)
            .contiguous()
            .view(nbatches, -1, self.h * self.d_k)
        )
        del query
        del key
        del value
        return self.linears[-1](x)


class PositionwiseFeedForward(nn.Module):
    "Implements FFN equation."

    def __init__(self, d_model, d_ff, dropout=0.1):
        super(PositionwiseFeedForward, self).__init__()
        self.w_1 = nn.Linear(d_model, d_ff)
        self.w_2 = nn.Linear(d_ff, d_model)
        self.dropout = nn.Dropout(dropout)

    def forward(self, x):
        return self.w_2(self.dropout(self.w_1(x).relu()))


class Embeddings(nn.Module):
    def __init__(self, d_model, vocab):
        super(Embeddings, self).__init__()
        self.lut = nn.Embedding(vocab, d_model)
        self.d_model = d_model
    def forward(self, x):
        return self.lut(x) * math.sqrt(self.d_model)


class PositionalEncoding(nn.Module):
    "Implement the PE function."

    def __init__(self, d_model, dropout, max_len=5000):
        super(PositionalEncoding, self).__init__()
        self.dropout = nn.Dropout(p=dropout)

        # Compute the positional encodings once in log space.
        pe = torch.zeros(max_len, d_model)
        position = torch.arange(0, max_len).unsqueeze(1)
        div_term = torch.exp(
            torch.arange(0, d_model, 2) * -(math.log(10000.0) / d_model)
        )
        pe[:, 0::2] = torch.sin(position * div_term)
        pe[:, 1::2] = torch.cos(position * div_term)
        pe = pe.unsqueeze(0)
        self.register_buffer("pe", pe)

    def forward(self, x):
        x = x + self.pe[:, : x.size(1)].requires_grad_(False)
        return self.dropout(x)


def example_positional():
    pe = PositionalEncoding(20, 0)
    y = pe.forward(torch.zeros(1, 100, 20))

    data = pd.concat(
        [
            pd.DataFrame(
                {
                    "embedding": y[0, :, dim],
                    "dimension": dim,
                    "position": list(range(100)),
                }
            )
            for dim in [4, 5, 6, 7]
        ]
    )

    return (
        alt.Chart(data)
        .mark_line()
        .properties(width=800)
        .encode(x="position", y="embedding", color="dimension:N")
        .interactive()
    )


show_example(example_positional)
```



```
def make_model(
    src_vocab, tgt_vocab, N=6, d_model=512, d_ff=2048, h=8, dropout=0.1
):
    "Helper: Construct a model from hyperparameters."
    c = copy.deepcopy
    attn = MultiHeadedAttention(h, d_model)
    ff = PositionwiseFeedForward(d_model, d_ff, dropout)
    position = PositionalEncoding(d_model, dropout)
    model = EncoderDecoder(
        Encoder(EncoderLayer(d_model, c(attn), c(ff), dropout), N),
        Decoder(DecoderLayer(d_model, c(attn), c(attn), c(ff), dropout), N),
        nn.Sequential(Embeddings(d_model, src_vocab), c(position)),
        nn.Sequential(Embeddings(d_model, tgt_vocab), c(position)),
        Generator(d_model, tgt_vocab),
    )

    # This was important from their code.
    # Initialize parameters with Glorot / fan_avg.
    for p in model.parameters():
        if p.dim() > 1:
            nn.init.xavier_uniform_(p)
    return model


def·inference_test():
····test_model·=·make_model(11,·11,·2)
····test_model.eval()
····src·=·torch.LongTensor([[1,·2,·3,·4,·5,·6,·7,·8,·9,·10]])
····src_mask·=·torch.ones(1,·1,·10)

····memory·=·test_model.encode(src,·src_mask)
····ys·=·torch.zeros(1,·1).type_as(src)

····for·i·in·range(9):
········out·=·test_model.decode(
············memory,·src_mask,·ys,·subsequent_mask(ys.size(1)).type_as(src.data)
········)
········prob·=·test_model.generator(out[:,·-1])
········_,·next_word·=·torch.max(prob,·dim=1)
········next_word·=·next_word.data[0]
········ys·=·torch.cat(
············[ys,·torch.empty(1,·1).type_as(src.data).fill_(next_word)],·dim=1
········)

····print("Example·Untrained·Model·Prediction:",·ys)


def·run_tests():
····for·_·in·range(10):
········inference_test()


show_example(run_tests)
```

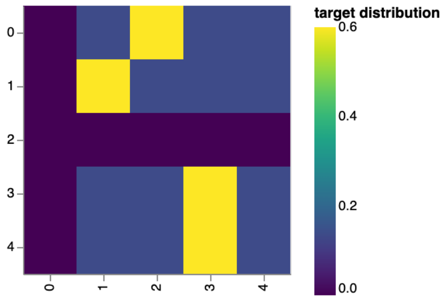
```
Example Untrained Model Prediction: tensor([[0, 8, 9, 9, 9, 9, 9, 9, 9, 9]])
Example Untrained Model Prediction: tensor([[0, 6, 6, 6, 6, 6, 6, 6, 6, 6]])
Example Untrained Model Prediction: tensor([[0, 2, 2, 2, 2, 2, 2, 2, 2, 2]])
Example Untrained Model Prediction: tensor([[0, 6, 0, 6, 0, 6, 0, 6, 3, 2]])
Example Untrained Model Prediction: tensor([[0, 1, 6, 1, 9, 1, 9, 1, 0, 1]])
Example Untrained Model Prediction: tensor([[ 0,  3,  5,  7,  5, 10, 10, 10, 10, 10]])
Example Untrained Model Prediction: tensor([[0, 2, 6, 6, 2, 6, 2, 6, 2, 6]])
Example Untrained Model Prediction: tensor([[0, 7, 4, 1, 6, 4, 1, 6, 4, 1]])
Example Untrained Model Prediction: tensor([[0, 0, 0, 0, 0, 0, 0, 0, 0, 0]])
Example Untrained Model Prediction: tensor([[ 0, 10,  7, 10,  7, 10,  7, 10,  7,  0]])
```

```
class Batch:
    """Object for holding a batch of data with mask during training."""

    def __init__(self, src, tgt=None, pad=2):  # 2 = <blank>
        self.src = src
        self.src_mask = (src != pad).unsqueeze(-2)
        if tgt is not None:
            self.tgt = tgt[:, :-1]
            self.tgt_y = tgt[:, 1:]
            self.tgt_mask = self.make_std_mask(self.tgt, pad)
            self.ntokens = (self.tgt_y != pad).data.sum()

    @staticmethod
    def make_std_mask(tgt, pad):
        "Create a mask to hide padding and future words."
        tgt_mask = (tgt != pad).unsqueeze(-2)
        tgt_mask = tgt_mask & subsequent_mask(tgt.size(-1)).type_as(
            tgt_mask.data
        )
        return tgt_mask



class TrainState:
    """Track number of steps, examples, and tokens processed"""

    step: int = 0  # Steps in the current epoch
    accum_step: int = 0  # Number of gradient accumulation steps
    samples: int = 0  # total # of examples used
    tokens: int = 0  # total # of tokens processed



def run_epoch(
    data_iter,
    model,
    loss_compute,
    optimizer,
    scheduler,
    mode="train",
    accum_iter=1,
    train_state=TrainState(),
):
    """Train a single epoch"""
    start = time.time()
    total_tokens = 0
    total_loss = 0
    tokens = 0
    n_accum = 0
    for i, batch in enumerate(data_iter):
        out = model.forward(
            batch.src, batch.tgt, batch.src_mask, batch.tgt_mask
        )
        loss, loss_node = loss_compute(out, batch.tgt_y, batch.ntokens)
        # loss_node = loss_node / accum_iter
        if mode == "train" or mode == "train+log":
            loss_node.backward()
            train_state.step += 1
            train_state.samples += batch.src.shape[0]
            train_state.tokens += batch.ntokens
            if i % accum_iter == 0:
                optimizer.step()
                optimizer.zero_grad(set_to_none=True)
                n_accum += 1
                train_state.accum_step += 1
            scheduler.step()

        total_loss += loss
        total_tokens += batch.ntokens
        tokens += batch.ntokens
        if i % 40 == 1 and (mode == "train" or mode == "train+log"):
            lr = optimizer.param_groups[0]["lr"]
            elapsed = time.time() - start
            print(
                (
                    "Epoch Step: %6d | Accumulation Step: %3d | Loss: %6.2f "
                    + "| Tokens / Sec: %7.1f | Learning Rate: %6.1e"
                )
                % (i, n_accum, loss / batch.ntokens, tokens / elapsed, lr)
            )
            start = time.time()
            tokens = 0
        del loss
        del loss_node
    return total_loss / total_tokens, train_state


def rate(step, model_size, factor, warmup):
    """
    we have to default the step to 1 for LambdaLR function
    to avoid zero raising to negative power.
    """
    if step == 0:
        step = 1
    return factor * (
        model_size ** (-0.5) * min(step ** (-0.5), step * warmup ** (-1.5))
    )


def example_learning_schedule():
    opts = [
        [512, 1, 4000],  # example 1
        [512, 1, 8000],  # example 2
        [256, 1, 4000],  # example 3
    ]

    dummy_model = torch.nn.Linear(1, 1)
    learning_rates = []

    # we have 3 examples in opts list.
    for idx, example in enumerate(opts):
        # run 20000 epoch for each example
        optimizer = torch.optim.Adam(
            dummy_model.parameters(), lr=1, betas=(0.9, 0.98), eps=1e-9
        )
        lr_scheduler = LambdaLR(
            optimizer=optimizer, lr_lambda=lambda step: rate(step, *example)
        )
        tmp = []
        # take 20K dummy training steps, save the learning rate at each step
        for step in range(20000):
            tmp.append(optimizer.param_groups[0]["lr"])
            optimizer.step()
            lr_scheduler.step()
        learning_rates.append(tmp)

    learning_rates = torch.tensor(learning_rates)

    # Enable altair to handle more than 5000 rows
    alt.data_transformers.disable_max_rows()

    opts_data = pd.concat(
        [
            pd.DataFrame(
                {
                    "Learning Rate": learning_rates[warmup_idx, :],
                    "model_size:warmup": ["512:4000", "512:8000", "256:4000"][
                        warmup_idx
                    ],
                    "step": range(20000),
                }
            )
            for warmup_idx in [0, 1, 2]
        ]
    )

    return (
        alt.Chart(opts_data)
        .mark_line()
        .properties(width=600)
        .encode(x="step", y="Learning Rate", color="model_size:warmup:N")
        .interactive()
    )


example_learning_schedule()
```



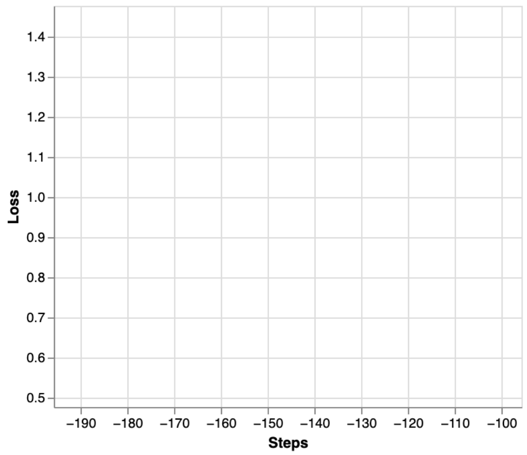
```
class LabelSmoothing(nn.Module):
    "Implement label smoothing."

    def __init__(self, size, padding_idx, smoothing=0.0):
        super(LabelSmoothing, self).__init__()
        self.criterion = nn.KLDivLoss(reduction="sum")
        self.padding_idx = padding_idx
        self.confidence = 1.0 - smoothing
        self.smoothing = smoothing
        self.size = size
        self.true_dist = None

    def forward(self, x, target):
        assert x.size(1) == self.size
        true_dist = x.data.clone()
        true_dist.fill_(self.smoothing / (self.size - 2))
        true_dist.scatter_(1, target.data.unsqueeze(1), self.confidence)
        true_dist[:, self.padding_idx] = 0
        mask = torch.nonzero(target.data == self.padding_idx)
        if mask.dim() > 0:
            true_dist.index_fill_(0, mask.squeeze(), 0.0)
        self.true_dist = true_dist
        return self.criterion(x, true_dist.clone().detach())


# Example of label smoothing.


def example_label_smoothing():
    crit = LabelSmoothing(5, 0, 0.4)
    predict = torch.FloatTensor(
        [
            [0, 0.2, 0.7, 0.1, 0],
            [0, 0.2, 0.7, 0.1, 0],
            [0, 0.2, 0.7, 0.1, 0],
            [0, 0.2, 0.7, 0.1, 0],
            [0, 0.2, 0.7, 0.1, 0],
        ]
    )
    crit(x=predict.log(), target=torch.LongTensor([2, 1, 0, 3, 3]))
    LS_data = pd.concat(
        [
            pd.DataFrame(
                {
                    "target distribution": crit.true_dist[x, y].flatten(),
                    "columns": y,
                    "rows": x,
                }
            )
            for y in range(5)
            for x in range(5)
        ]
    )

    return (
        alt.Chart(LS_data)
        .mark_rect(color="Blue", opacity=1)
        .properties(height=200, width=200)
        .encode(
            alt.X("columns:O", title=None),
            alt.Y("rows:O", title=None),
            alt.Color(
                "target distribution:Q", scale=alt.Scale(scheme="viridis")
            ),
        )
        .interactive()
    )
```

```
show_example(example_label_smoothing)
```



```
def loss(x, crit):
    d = x + 3 * 1
    predict = torch.FloatTensor([[0, x / d, 1 / d, 1 / d, 1 / d]])
    return crit(predict.log(), torch.LongTensor([1])).data


def penalization_visualization():
    crit = LabelSmoothing(5, 0, 0.1)
    loss_data = pd.DataFrame(
        {
            "Loss": [loss(x, crit) for x in range(1, 100)],
            "Steps": list(range(99)),
        }
    ).astype("float")

    return (
        alt.Chart(loss_data)
        .mark_line()
        .properties(width=350)
        .encode(
            x="Steps",
            y="Loss",
        )
        .interactive()
    )
```

```
show_example(penalization_visualization)
```



```
def data_gen(V, batch_size, nbatches):
    "Generate random data for a src-tgt copy task."
    for i in range(nbatches):
        data = torch.randint(1, V, size=(batch_size, 10))
        data[:, 0] = 1
        src = data.requires_grad_(False).clone().detach()
        tgt = data.requires_grad_(False).clone().detach()
        yield Batch(src, tgt, 0)
```

```python
class SimpleLossCompute:
    "A simple loss compute and train function."

    def __init__(self, generator, criterion):
        self.generator = generator
        self.criterion = criterion

    def __call__(self, x, y, norm):
        x = self.generator(x)
        sloss = (
            self.criterion(
                x.contiguous().view(-1, x.size(-1)), y.contiguous().view(-1)
            )
            / norm
        )
        return sloss.data * norm, sloss


def greedy_decode(model, src, src_mask, max_len, start_symbol):
    memory = model.encode(src, src_mask)
    ys = torch.zeros(1, 1).fill_(start_symbol).type_as(src.data)
    for i in range(max_len - 1):
        out = model.decode(
            memory, src_mask, ys, subsequent_mask(ys.size(1)).type_as(src.data)
        )
        prob = model.generator(out[:, -1])
        _, next_word = torch.max(prob, dim=1)
        next_word = next_word.data[0]
        ys = torch.cat(
            [ys, torch.zeros(1, 1).type_as(src.data).fill_(next_word)], dim=1
        )
    return ys


# Train the simple copy task.


def example_simple_model():
    V = 11
    criterion = LabelSmoothing(size=V, padding_idx=0, smoothing=0.0)
    model = make_model(V, V, N=2)

    optimizer = torch.optim.Adam(
        model.parameters(), lr=0.5, betas=(0.9, 0.98), eps=1e-9
    )
    lr_scheduler = LambdaLR(
        optimizer=optimizer,
        lr_lambda=lambda step: rate(
            step, model_size=model.src_embed[0].d_model, factor=1.0, warmup=400
        ),
    )

    batch_size = 80
    for epoch in range(20):
        model.train()
        run_epoch(
            data_gen(V, batch_size, 20),
            model,
            SimpleLossCompute(model.generator, criterion),
            optimizer,
            lr_scheduler,
            mode="train",
        )
        model.eval()
        run_epoch(
            data_gen(V, batch_size, 5),
            model,
            SimpleLossCompute(model.generator, criterion),
            DummyOptimizer(),
            DummyScheduler(),
            mode="eval",
        )[0]

    model.eval()
    src = torch.LongTensor([[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]])
    max_len = src.shape[1]
    src_mask = torch.ones(1, 1, max_len)
    print(greedy_decode(model, src, src_mask, max_len=max_len, start_symbol=0))


# execute_example(example_simple_model)


# Load spacy tokenizer models, download them if they haven't been
# downloaded already


def load_tokenizers():

    try:
        spacy_de = spacy.load("de_core_news_sm")
    except IOError:
        os.system("python -m spacy download de_core_news_sm")
        spacy_de = spacy.load("de_core_news_sm")

    try:
        spacy_en = spacy.load("en_core_web_sm")
    except IOError:
        os.system("python -m spacy download en_core_web_sm")
        spacy_en = spacy.load("en_core_web_sm")

    return spacy_de, spacy_en


def tokenize(text, tokenizer):
    return [tok.text for tok in tokenizer.tokenizer(text)]


def yield_tokens(data_iter, tokenizer, index):
    for from_to_tuple in data_iter:
        yield tokenizer(from_to_tuple[index])




def build_vocabulary(spacy_de, spacy_en):
    def tokenize_de(text):
        return tokenize(text, spacy_de)

    def tokenize_en(text):
        return tokenize(text, spacy_en)

    print("Building German Vocabulary ...")
    train, val, test = datasets.Multi30k(language_pair=("de", "en"))
    vocab_src = build_vocab_from_iterator(
        yield_tokens(train + val + test, tokenize_de, index=0),
        min_freq=2,
        specials=["<s>", "</s>", "<blank>", "<unk>"],
    )

    print("Building English Vocabulary ...")
    train, val, test = datasets.Multi30k(language_pair=("de", "en"))
    vocab_tgt = build_vocab_from_iterator(
        yield_tokens(train + val + test, tokenize_en, index=1),
        min_freq=2,
        specials=["<s>", "</s>", "<blank>", "<unk>"],
    )

    vocab_src.set_default_index(vocab_src["<unk>"])
    vocab_tgt.set_default_index(vocab_tgt["<unk>"])

    return vocab_src, vocab_tgt


def load_vocab(spacy_de, spacy_en):
    if not exists("vocab.pt"):
        vocab_src, vocab_tgt = build_vocabulary(spacy_de, spacy_en)
        torch.save((vocab_src, vocab_tgt), "vocab.pt")
    else:
        vocab_src, vocab_tgt = torch.load("vocab.pt")
    print("Finished.\nVocabulary sizes:")
    print(len(vocab_src))
    print(len(vocab_tgt))
    return vocab_src, vocab_tgt
```

```
if is_interactive_notebook():
    # global variables used later in the script
    spacy_de, spacy_en = show_example(load_tokenizers)
    vocab_src, vocab_tgt = show_example(load_vocab, args=[spacy_de, spacy_en])
```

```
Building German Vocabulary ...
Building English Vocabulary ...
Finished.
Vocabulary sizes:
8315
6384
```

```
def collate_batch(
    batch,
    src_pipeline,
    tgt_pipeline,
    src_vocab,
    tgt_vocab,
    device,
    max_padding=128,
    pad_id=2,
):
    bs_id = torch.tensor([0], device=device)  # <s> token id
    eos_id = torch.tensor([1], device=device)  # </s> token id
    src_list, tgt_list = [], []
    for (_src, _tgt) in batch:
        processed_src = torch.cat(
            [
                bs_id,
                torch.tensor(
                    src_vocab(src_pipeline(_src)),
                    dtype=torch.int64,
                    device=device,
                ),
                eos_id,
            ],
            0,
        )
        processed_tgt = torch.cat(
            [
                bs_id,
                torch.tensor(
                    tgt_vocab(tgt_pipeline(_tgt)),
                    dtype=torch.int64,
                    device=device,
                ),
                eos_id,
            ],
            0,
        )
        src_list.append(
            # warning - overwrites values for negative values of padding - len
            pad(
                processed_src,
                (
                    0,
                    max_padding - len(processed_src),
                ),
                value=pad_id,
            )
        )
        tgt_list.append(
            pad(
                processed_tgt,
                (0, max_padding - len(processed_tgt)),
                value=pad_id,
            )
        )

    src = torch.stack(src_list)
    tgt = torch.stack(tgt_list)
    return (src, tgt)


def create_dataloaders(
    device,
    vocab_src,
    vocab_tgt,
    spacy_de,
    spacy_en,
    batch_size=12000,
    max_padding=128,
    is_distributed=True,
):
    # def create_dataloaders(batch_size=12000):
    def tokenize_de(text):
        return tokenize(text, spacy_de)

    def tokenize_en(text):
        return tokenize(text, spacy_en)

    def collate_fn(batch):
        return collate_batch(
            batch,
            tokenize_de,
            tokenize_en,
            vocab_src,
            vocab_tgt,
            device,
            max_padding=max_padding,
            pad_id=vocab_src.get_stoi()["<blank>"],
        )

    train_iter, valid_iter, test_iter = datasets.Multi30k(
        language_pair=("de", "en")
    )

    train_iter_map = to_map_style_dataset(
        train_iter
    )  # DistributedSampler needs a dataset len()
    train_sampler = (
        DistributedSampler(train_iter_map) if is_distributed else None
    )
    valid_iter_map = to_map_style_dataset(valid_iter)
    valid_sampler = (
        DistributedSampler(valid_iter_map) if is_distributed else None
    )

    train_dataloader = DataLoader(
        train_iter_map,
        batch_size=batch_size,
        shuffle=(train_sampler is None),
        sampler=train_sampler,
        collate_fn=collate_fn,
    )
    valid_dataloader = DataLoader(
        valid_iter_map,
        batch_size=batch_size,
        shuffle=(valid_sampler is None),
        sampler=valid_sampler,
        collate_fn=collate_fn,
    )
    return train_dataloader, valid_dataloader


def train_worker(
    gpu,
    ngpus_per_node,
    vocab_src,
    vocab_tgt,
    spacy_de,
    spacy_en,
    config,
    is_distributed=False,
):
    print(f"Train worker process using GPU: {gpu} for training", flush=True)
    torch.cuda.set_device(gpu)

    pad_idx = vocab_tgt["<blank>"]
    d_model = 512
    model = make_model(len(vocab_src), len(vocab_tgt), N=6)
    model.cuda(gpu)
    module = model
    is_main_process = True
    if is_distributed:
        dist.init_process_group(
            "nccl", init_method="env://", rank=gpu, world_size=ngpus_per_node
        )
        model = DDP(model, device_ids=[gpu])
        module = model.module
        is_main_process = gpu == 0

    criterion = LabelSmoothing(
        size=len(vocab_tgt), padding_idx=pad_idx, smoothing=0.1
    )
    criterion.cuda(gpu)

    train_dataloader, valid_dataloader = create_dataloaders(
        gpu,
        vocab_src,
        vocab_tgt,
        spacy_de,
        spacy_en,
        batch_size=config["batch_size"] // ngpus_per_node,
        max_padding=config["max_padding"],
        is_distributed=is_distributed,
    )

    optimizer = torch.optim.Adam(
        model.parameters(), lr=config["base_lr"], betas=(0.9, 0.98), eps=1e-9
    )
    lr_scheduler = LambdaLR(
        optimizer=optimizer,
        lr_lambda=lambda step: rate(
            step, d_model, factor=1, warmup=config["warmup"]
        ),
    )
    train_state = TrainState()

    for epoch in range(config["num_epochs"]):
        if is_distributed:
            train_dataloader.sampler.set_epoch(epoch)
            valid_dataloader.sampler.set_epoch(epoch)

        model.train()
        print(f"[GPU{gpu}] Epoch {epoch} Training ====", flush=True)
        _, train_state = run_epoch(
            (Batch(b[0], b[1], pad_idx) for b in train_dataloader),
            model,
            SimpleLossCompute(module.generator, criterion),
            optimizer,
            lr_scheduler,
            mode="train+log",
            accum_iter=config["accum_iter"],
            train_state=train_state,
        )

        GPUtil.showUtilization()
        if is_main_process:
            file_path = "%s%.2d.pt" % (config["file_prefix"], epoch)
            torch.save(module.state_dict(), file_path)
        torch.cuda.empty_cache()

        print(f"[GPU{gpu}] Epoch {epoch} Validation ====", flush=True)
        model.eval()
        sloss = run_epoch(
            (Batch(b[0], b[1], pad_idx) for b in valid_dataloader),
            model,
            SimpleLossCompute(module.generator, criterion),
            DummyOptimizer(),
            DummyScheduler(),
            mode="eval",
        )
        print(sloss)
        torch.cuda.empty_cache()

    if is_main_process:
        file_path = "%sfinal.pt" % config["file_prefix"]
        torch.save(module.state_dict(), file_path)
```

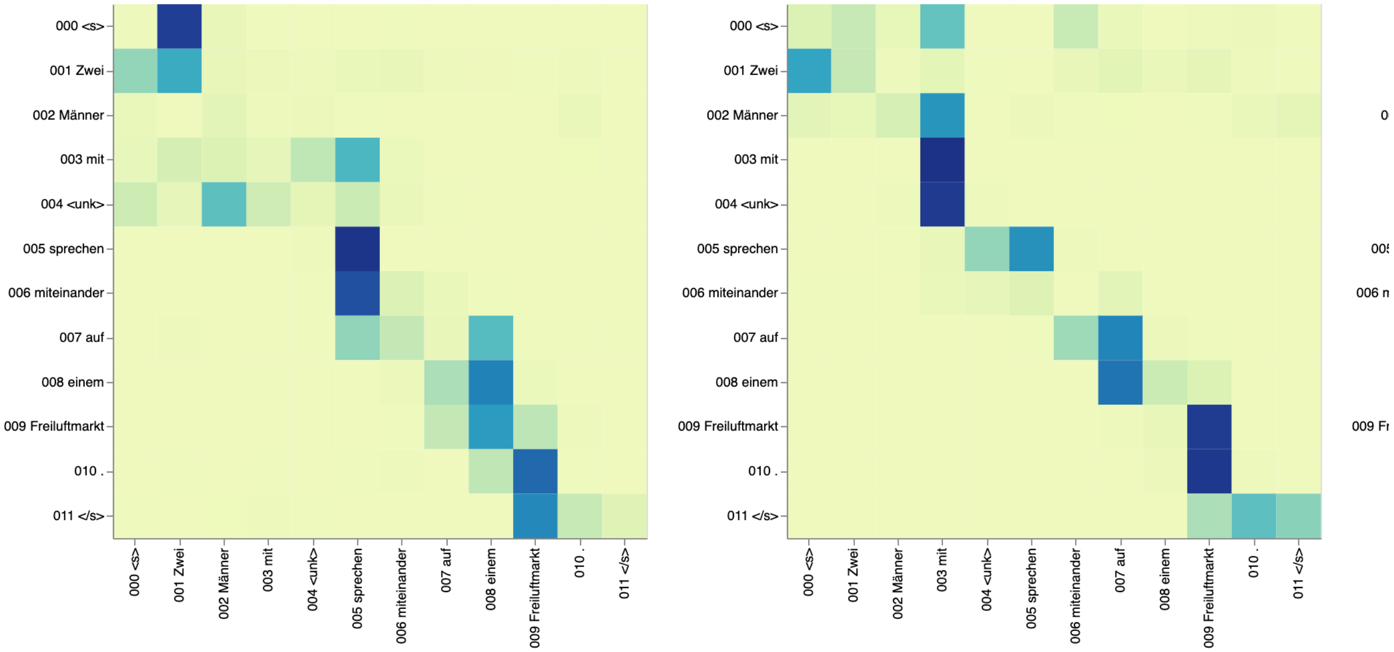
```python
#@title
def train_distributed_model(vocab_src, vocab_tgt, spacy_de, spacy_en, config):
    from the_annotated_transformer import train_worker

    ngpus = torch.cuda.device_count()
    os.environ["MASTER_ADDR"] = "localhost"
    os.environ["MASTER_PORT"] = "12356"
    print(f"Number of GPUs detected: {ngpus}")
    print("Spawning training processes ...")
    mp.spawn(
        train_worker,
        nprocs=ngpus,
        args=(ngpus, vocab_src, vocab_tgt, spacy_de, spacy_en, config, True),
    )


def train_model(vocab_src, vocab_tgt, spacy_de, spacy_en, config):
    if config["distributed"]:
        train_distributed_model(
            vocab_src, vocab_tgt, spacy_de, spacy_en, config
        )
    else:
        train_worker(
            0, 1, vocab_src, vocab_tgt, spacy_de, spacy_en, config, False
        )


def load_trained_model():
    config = {
        "batch_size": 32,
        "distributed": False,
        "num_epochs": 8,
        "accum_iter": 10,
        "base_lr": 1.0,
        "max_padding": 72,
        "warmup": 3000,
        "file_prefix": "multi30k_model_",
    }
    model_path = "multi30k_model_final.pt"
    if not exists(model_path):
        train_model(vocab_src, vocab_tgt, spacy_de, spacy_en, config)

    model = make_model(len(vocab_src), len(vocab_tgt), N=6)
    model.load_state_dict(torch.load("multi30k_model_final.pt"))
    return model


if is_interactive_notebook():
    model = load_trained_model()
```

```
[GPU0] Epoch 7 Training ====
Epoch Step:      1 | Accumulation Step:   1 | Loss:   1.14 | Tokens / Sec:  1999.9 | Learning Rate: 5.5e-04
Epoch Step:     41 | Accumulation Step:   5 | Loss:   1.13 | Tokens / Sec:  1656.8 | Learning Rate: 5.5e-04
Epoch Step:     81 | Accumulation Step:   9 | Loss:   1.04 | Tokens / Sec:  1660.9 | Learning Rate: 5.5e-04
Epoch Step:    121 | Accumulation Step:  13 | Loss:   0.98 | Tokens / Sec:  1695.5 | Learning Rate: 5.5e-04
Epoch Step:    161 | Accumulation Step:  17 | Loss:   0.99 | Tokens / Sec:  1669.0 | Learning Rate: 5.5e-04
Epoch Step:    201 | Accumulation Step:  21 | Loss:   1.01 | Tokens / Sec:  1666.6 | Learning Rate: 5.5e-04
Epoch Step:    241 | Accumulation Step:  25 | Loss:   1.08 | Tokens / Sec:  1675.9 | Learning Rate: 5.4e-04
Epoch Step:    281 | Accumulation Step:  29 | Loss:   0.82 | Tokens / Sec:  1648.3 | Learning Rate: 5.4e-04
Epoch Step:    321 | Accumulation Step:  33 | Loss:   1.12 | Tokens / Sec:  1666.6 | Learning Rate: 5.4e-04
Epoch Step:    361 | Accumulation Step:  37 | Loss:   0.93 | Tokens / Sec:  1676.4 | Learning Rate: 5.4e-04
Epoch Step:    401 | Accumulation Step:  41 | Loss:   1.07 | Tokens / Sec:  1676.0 | Learning Rate: 5.4e-04
Epoch Step:    441 | Accumulation Step:  45 | Loss:   1.10 | Tokens / Sec:  1653.9 | Learning Rate: 5.4e-04
Epoch Step:    481 | Accumulation Step:  49 | Loss:   1.21 | Tokens / Sec:  1675.2 | Learning Rate: 5.3e-04
Epoch Step:    521 | Accumulation Step:  53 | Loss:   0.96 | Tokens / Sec:  1674.4 | Learning Rate: 5.3e-04
Epoch Step:    561 | Accumulation Step:  57 | Loss:   1.10 | Tokens / Sec:  1668.3 | Learning Rate: 5.3e-04
Epoch Step:    601 | Accumulation Step:  61 | Loss:   1.14 | Tokens / Sec:  1678.2 | Learning Rate: 5.3e-04
Epoch Step:    641 | Accumulation Step:  65 | Loss:   0.99 | Tokens / Sec:  1675.3 | Learning Rate: 5.3e-04
Epoch Step:    681 | Accumulation Step:  69 | Loss:   1.07 | Tokens / Sec:  1666.3 | Learning Rate: 5.3e-04
Epoch Step:    721 | Accumulation Step:  73 | Loss:   1.17 | Tokens / Sec:  1681.1 | Learning Rate: 5.3e-04
Epoch Step:    761 | Accumulation Step:  77 | Loss:   1.16 | Tokens / Sec:  1657.9 | Learning Rate: 5.2e-04
Epoch Step:    801 | Accumulation Step:  81 | Loss:   1.19 | Tokens / Sec:  1682.5 | Learning Rate: 5.2e-04
Epoch Step:    841 | Accumulation Step:  85 | Loss:   1.18 | Tokens / Sec:  1698.1 | Learning Rate: 5.2e-04
Epoch Step:    881 | Accumulation Step:  89 | Loss:   1.05 | Tokens / Sec:  1657.0 | Learning Rate: 5.2e-04
| ID | GPU | MEM |
------------------
|  0 | 93% | 32% |
[GPU0] Epoch 7 Validation ====
(tensor(1.4417, device='cuda:0'), <__main__.TrainState object at 0x7fd3af1372b0>)
```

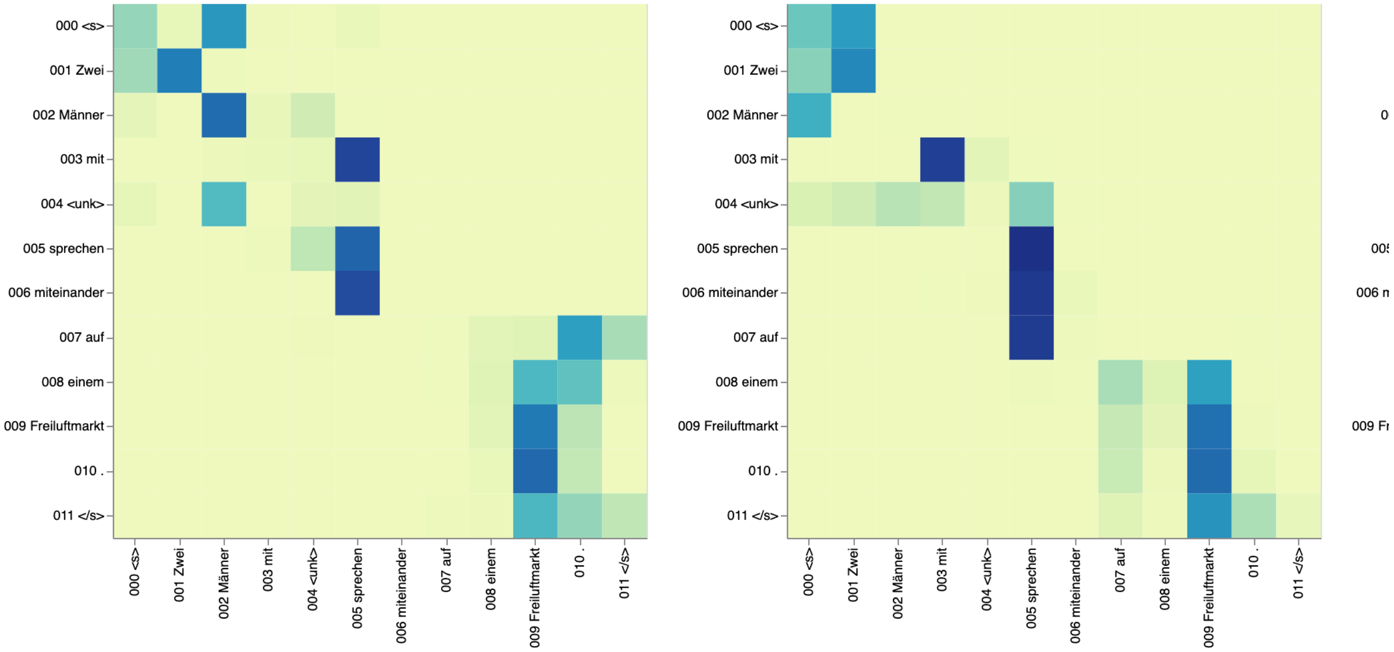
```python
#lets get into the results all down here
def check_outputs(
    valid_dataloader,
    model,
    vocab_src,
    vocab_tgt,
    n_examples=15,
    pad_idx=2,
    eos_string="</s>",
):
    results = [()] * n_examples
    for idx in range(n_examples):
        print("\nExample %d ========\n" % idx)
        b = next(iter(valid_dataloader))
        rb = Batch(b[0], b[1], pad_idx)
        greedy_decode(model, rb.src, rb.src_mask, 64, 0)[0]

        src_tokens = [
            vocab_src.get_itos()[x] for x in rb.src[0] if x != pad_idx
        ]
        tgt_tokens = [
            vocab_tgt.get_itos()[x] for x in rb.tgt[0] if x != pad_idx
        ]

        print(
            "Source Text (Input)        : "
            + " ".join(src_tokens).replace("\n", "")
        )
        print(
            "Target Text (Ground Truth) : "
            + " ".join(tgt_tokens).replace("\n", "")
        )
        model_out = greedy_decode(model, rb.src, rb.src_mask, 72, 0)[0]
        model_txt = (
            " ".join(
                [vocab_tgt.get_itos()[x] for x in model_out if x != pad_idx]
            ).split(eos_string, 1)[0]
            + eos_string
        )
        print("Model Output               : " + model_txt.replace("\n", ""))
        results[idx] = (rb, src_tokens, tgt_tokens, model_out, model_txt)
    return results


def run_model_example(n_examples=5):
    global vocab_src, vocab_tgt, spacy_de, spacy_en

    print("Preparing Data ...")
    _, valid_dataloader = create_dataloaders(
        torch.device("cpu"),
        vocab_src,
        vocab_tgt,
        spacy_de,
        spacy_en,
        batch_size=1,
        is_distributed=False,
    )

    print("Loading Trained Model ...")

    model = make_model(len(vocab_src), len(vocab_tgt), N=6)
    model.load_state_dict(
        torch.load("multi30k_model_final.pt", map_location=torch.device("cpu"))
    )

    print("Checking Model Outputs:")
    example_data = check_outputs(
        valid_dataloader, model, vocab_src, vocab_tgt, n_examples=n_examples
    )
    return model, example_data


# execute_example(run_model_example)


def mtx2df(m, max_row, max_col, row_tokens, col_tokens):
    "convert a dense matrix to a data frame with row and column indices"
    return pd.DataFrame(
        [
            (
                r,
                c,
                float(m[r, c]),
                "%.3d %s"
                % (r, row_tokens[r] if len(row_tokens) > r else "<blank>"),
                "%.3d %s"
                % (c, col_tokens[c] if len(col_tokens) > c else "<blank>"),
            )
            for r in range(m.shape[0])
            for c in range(m.shape[1])
            if r < max_row and c < max_col
        ],
        # if float(m[r,c]) != 0 and r < max_row and c < max_col],
        columns=["row", "column", "value", "row_token", "col_token"],
    )


def attn_map(attn, layer, head, row_tokens, col_tokens, max_dim=30):
    df = mtx2df(
        attn[0, head].data,
        max_dim,
        max_dim,
        row_tokens,
        col_tokens,
    )
    return (
        alt.Chart(data=df)
        .mark_rect()
        .encode(
            x=alt.X("col_token", axis=alt.Axis(title="")),
            y=alt.Y("row_token", axis=alt.Axis(title="")),
            color="value",
            tooltip=["row", "column", "value", "row_token", "col_token"],
        )
        .properties(height=400, width=400)
        .interactive()
    )


def get_encoder(model, layer):
    return model.encoder.layers[layer].self_attn.attn


def get_decoder_self(model, layer):
    return model.decoder.layers[layer].self_attn.attn


def get_decoder_src(model, layer):
    return model.decoder.layers[layer].src_attn.attn


def visualize_layer(model, layer, getter_fn, ntokens, row_tokens, col_tokens):
    # ntokens = last_example[0].ntokens
    attn = getter_fn(model, layer)
    n_heads = attn.shape[1]
    charts = [
        attn_map(
            attn,
            0,
            h,
            row_tokens=row_tokens,
            col_tokens=col_tokens,
            max_dim=ntokens,
        )
        for h in range(n_heads)
    ]
    assert n_heads == 8
    return alt.vconcat(
        charts[0]
        # | charts[1]
        | charts[2]
        # | charts[3]
        | charts[4]
        # | charts[5]
        | charts[6]
        # | charts[7]
        # layer + 1 due to 0-indexing
    ).properties(title="Layer %d" % (layer + 1))


def viz_encoder_self():
    model, example_data = run_model_example(n_examples=1)
    example = example_data[
        len(example_data) - 1
    ]  # batch object for the final example

    layer_viz = [
        visualize_layer(
            model, layer, get_encoder, len(example[1]), example[1], example[1]
        )
        for layer in range(6)
    ]
    return alt.hconcat(
        layer_viz[0]
        # & layer_viz[1]
        & layer_viz[2]
        # & layer_viz[3]
        & layer_viz[4]
        # & layer_viz[5]
    )


show_example(viz_encoder_self)
```

```
Preparing Data ...
Loading Trained Model ...
Checking Model Outputs:

Example 0 ========

Source Text (Input)        : <s> Zwei Männer mit <unk> sprechen miteinander auf einem Freiluftmarkt . </s>
Target Text (Ground Truth) : <s> Two men in <unk> 's have a discussion in an outdoor market . </s>
Model Output               : <s> Two men are talking to each other in an open air market . </s>
```

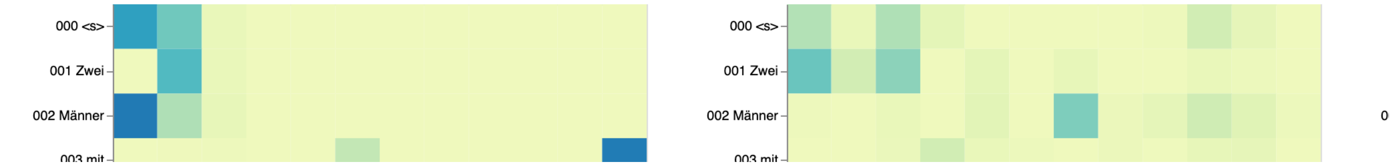
Layer 1



Layer 3



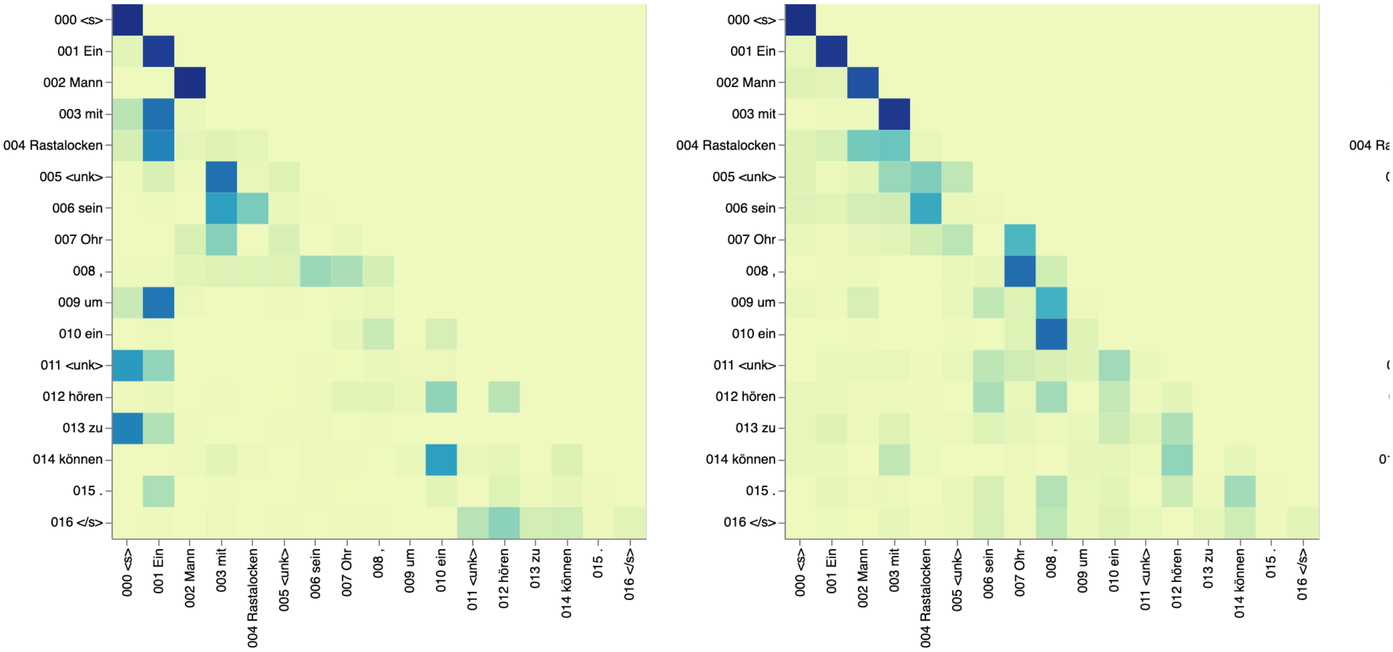
Layer 5



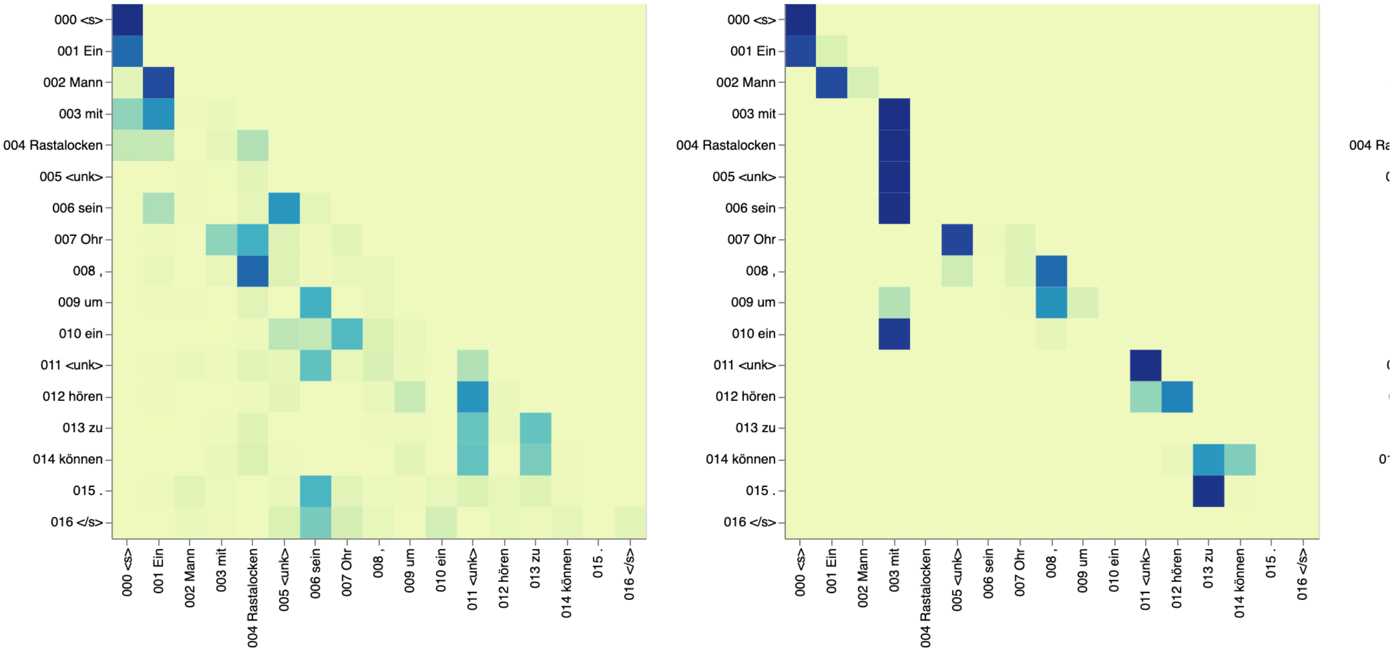
```
def viz_decoder_self():
    model, example_data = run_model_example(n_examples=1)
    example = example_data[len(example_data) - 1]

    layer_viz = [
        visualize_layer(
            model,
            layer,
            get_decoder_self,
            len(example[1]),
            example[1],
            example[1],
        )
        for layer in range(6)
    ]
    return alt.hconcat(
        layer_viz[0]
        & layer_viz[1]
        & layer_viz[2]
        & layer_viz[3]
        & layer_viz[4]
        & layer_viz[5]
    )


show_example(viz_decoder_self)
```

```
Preparing Data ...
Loading Trained Model ...
Checking Model Outputs:

Example 0 ========

Source Text (Input)        : <s> Ein Mann mit Rastalocken <unk> sein Ohr , um ein <unk> hören zu können . </s>
Target Text (Ground Truth) : <s> A man with dreadlocks is plugging his ear to hear a phone call . </s>
Model Output               : <s> A man with a <unk> hat is seen his ear to listen to be a music stand . </s>
```

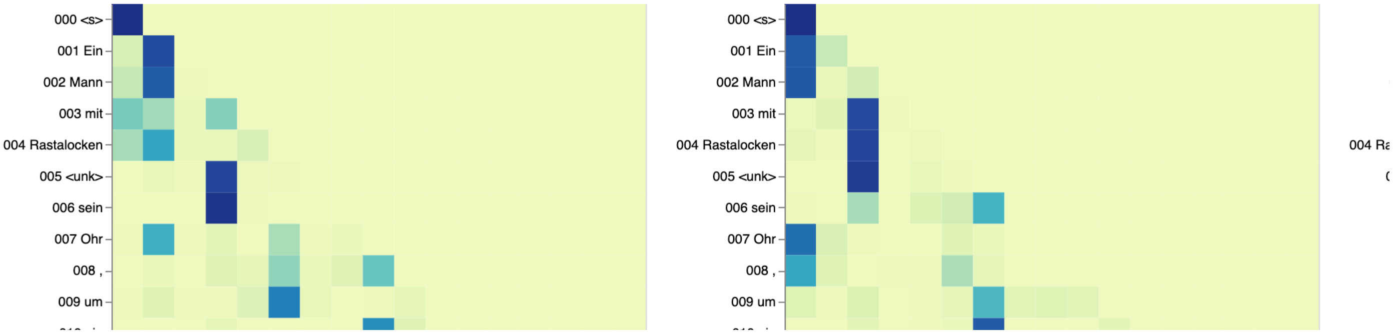
Layer 1



Layer 2



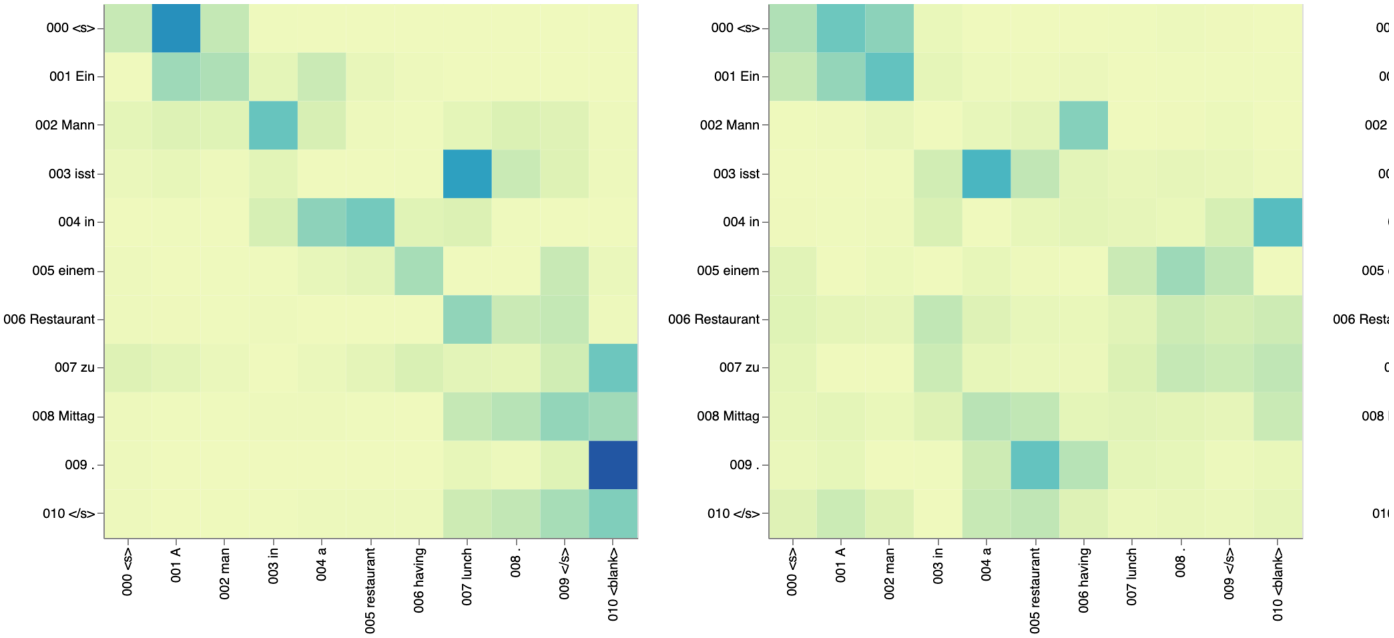
Layer 3



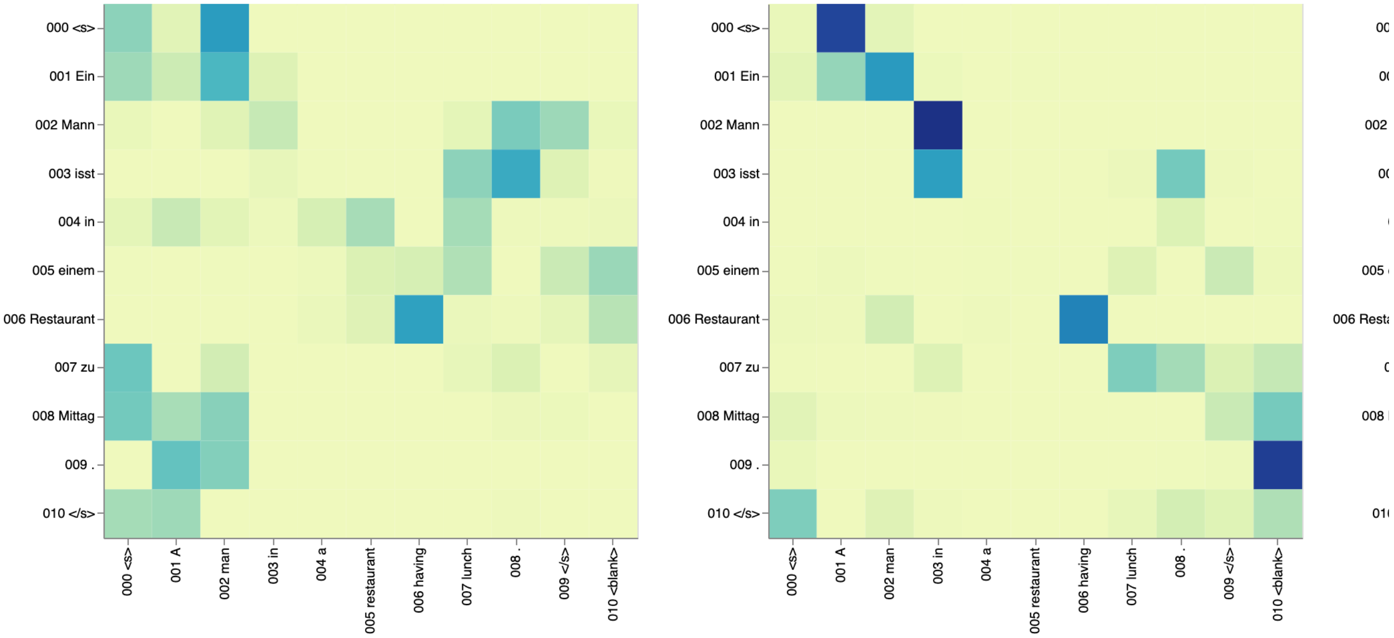
```
def viz_decoder_src():
    model, example_data = run_model_example(n_examples=1)
    example = example_data[len(example_data) - 1]

    layer_viz = [
        visualize_layer(
            model,
            layer,
            get_decoder_src,
            max(len(example[1]), len(example[2])),
            example[1],
            example[2],
        )
        for layer in range(6)
    ]
    return alt.hconcat(
        layer_viz[0]
        & layer_viz[1]
        & layer_viz[2]
        & layer_viz[3]
        & layer_viz[4]
        & layer_viz[5]
    )


show_example(viz_decoder_src)
```

```
Preparing Data ...
Loading Trained Model ...
Checking Model Outputs:

Example 0 ========

Source Text (Input)        : <s> Ein Mann isst in einem Restaurant zu Mittag . </s>
Target Text (Ground Truth) : <s> A man in a restaurant having lunch . </s>
Model Output               : <s> A man eats lunch to a restaurant . </s>
```

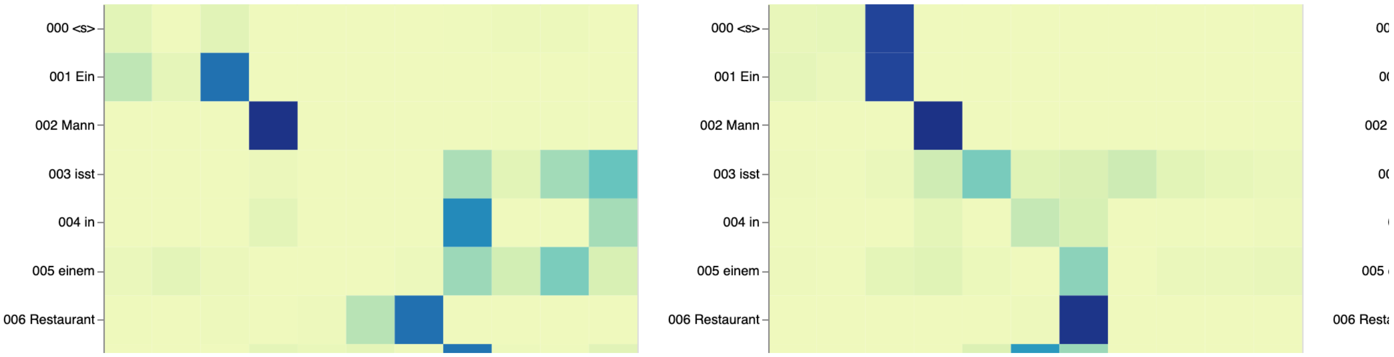
Layer 1

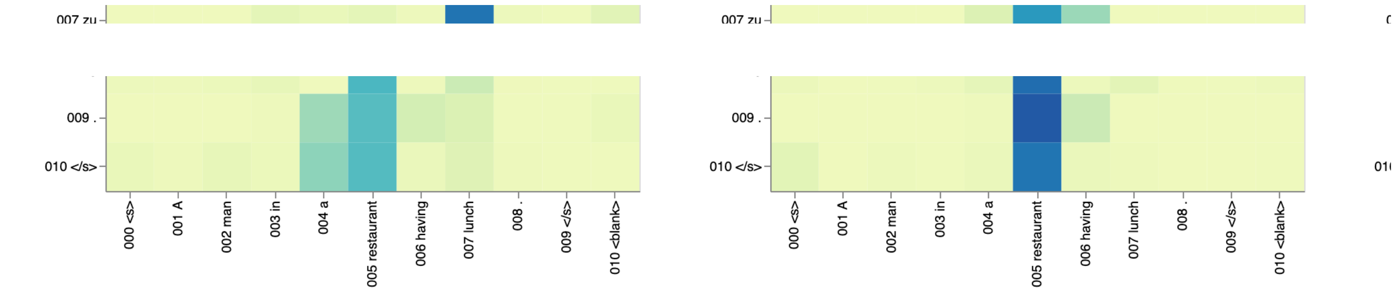


Layer 2

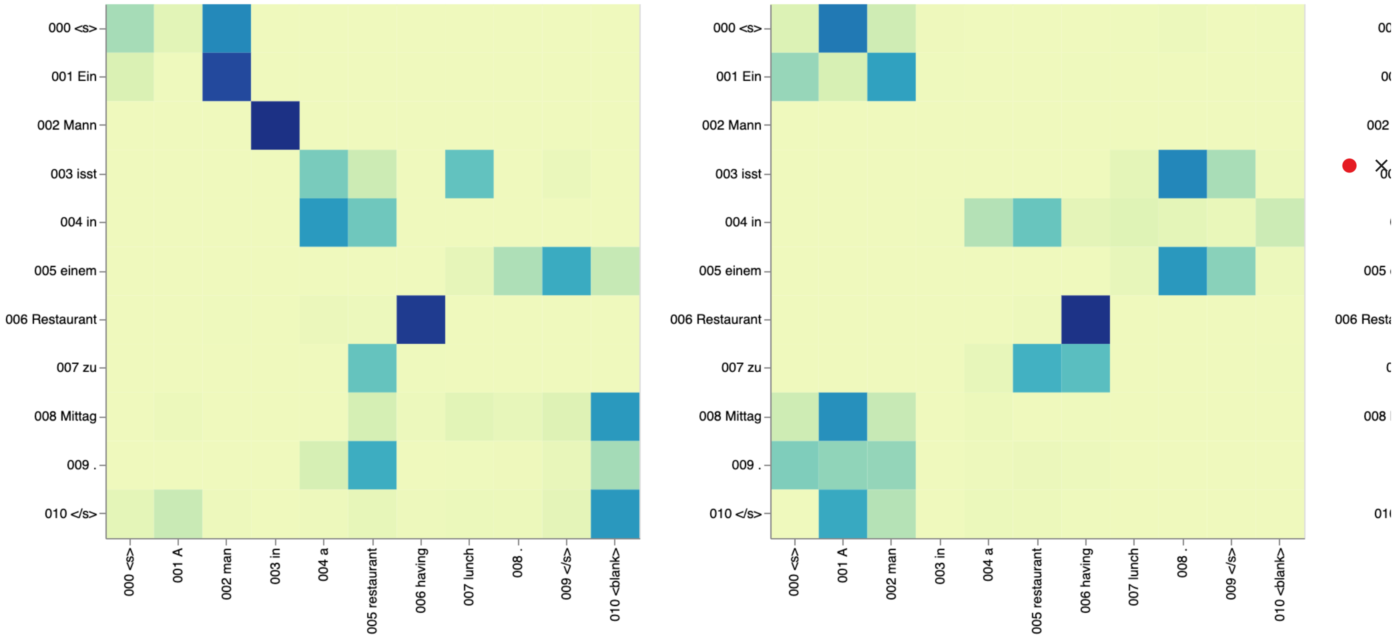


Layer 3

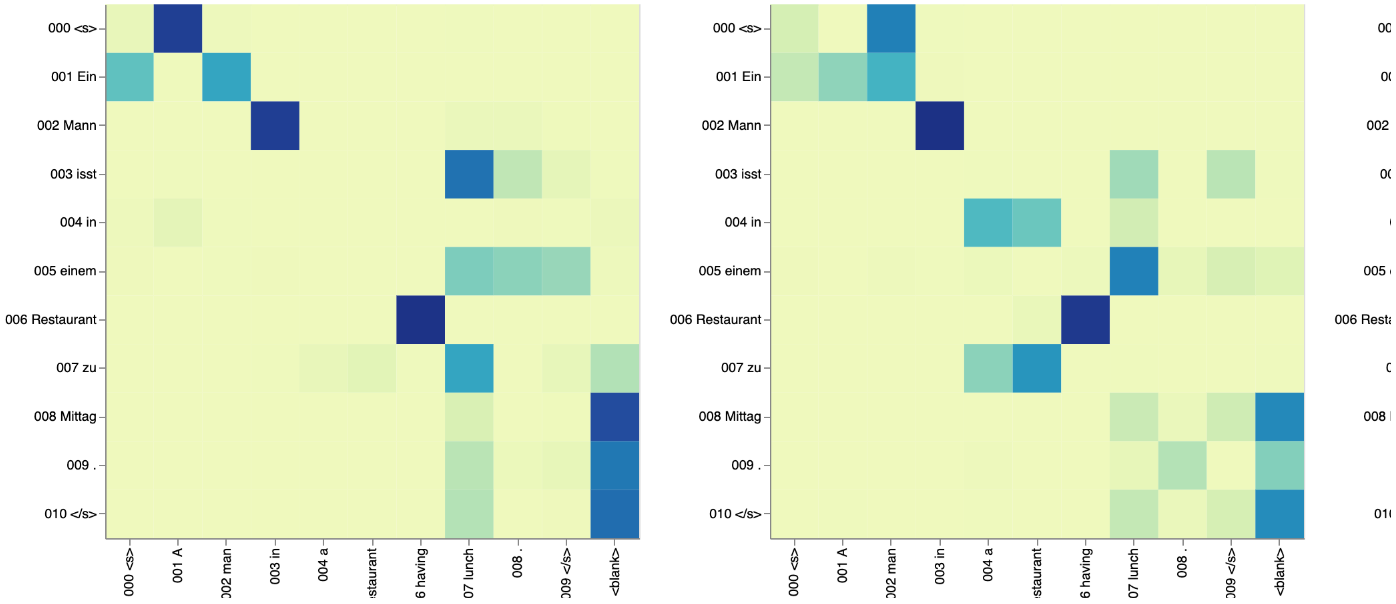




Layer 4



Layer 5


000 <s>
001 Ein
002 Mann
003 isst
004 in
005 einem
006 Restaurant
007 zu
008 Mittag
010 </s>
000 <s>
001 A
002 man
003 in
004 a
staurant
6 having
07 lunch
009 </s>
<blank>
000 <s>
001 Ein
002 Mann
003 isst
004 in
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006 Restaurant
007 zu
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000 <s>
001 A
002 man
003 in
004 a
staurant
6 having
07 lunch
009 </s>
<blank>
006 Resta