HW11

April 21, 2025

Please complete the `NotImplemented` parts of the code cells and write your answers in the markdown cells designated for your response to any questions asked. The tag `# AUTOGRADED` (all caps, with a space after `#`) should be at the beginning of each autograded code cell, so make sure that you do not change that. You are also not allowed to import any new package other than the ones already imported. Doing so will prevent the autograder from grading your code.

For the code submission, run the last cell in the notebook to create the submission zip file. If you are working in Colab, make sure to download and then upload a copy of the completed notebook itself to its working directory to be included in the zip file. Finally, submit the zip file to Gradescope.

After you finish the assignment and fill in your code and response where needed (all cells should have been run), save the notebook as a PDF using the `jupyter nbconvert --to pdf HW11.ipynb` command (via a notebook code cell or the command line directly) and submit the PDF to Gradescope under the PDF submission item. If you cannot get this to work locally, you can upload the notebook to Google Colab and create the PDF there. You can find the notebook containing the instruction for this on Canvas.

If you are running the notebook locally, make sure you have created a virtual environment (using `conda` for example) and have the proper packages installed. We are working with `python=3.10` and `torch>=2`.

Files to be included in submission:

- `HW11.ipynb`

[1]:
```
from typing import Union
from tqdm import tqdm
import numpy as np

import torch
from torch import nn, optim
from torch.nn import functional as F
from torch.utils.data import TensorDataset, Dataset, DataLoader

from torchvision.transforms import v2 as T
from torchvision.datasets import CIFAR10
from torchvision.models import resnet18

from google.colab import drive
drive.mount('/content/drive')
```

```
import os
os.chdir("/content/drive/MyDrive/24789HW11")

from HW11_utils import Tracker

if torch.cuda.is_available():
    Device = 'cuda'
elif torch.backends.mps.is_available():
    Device = 'mps'
else:
    Device = 'cpu'
print(f'Device is {Device}')
```

```
Mounted at /content/drive
Device is cuda
```

1 Contrastive loss functions (40)

A common loss function for contrastive learning is the NT-Xent loss introduced in SimCLR, which tries to maximize the cosine similarity between the features of the augmented data pairs that come from the same sample. The loss is a normalized temperature-scaled cross-entropy, i.e. NT-Xent, and is defined as follows for each pair:

$$\ell_{i,j} = -\log \frac{\exp(\text{sim}(\mathbf{z}_i, \mathbf{z}_j)/\tau)}{\sum_{k=1}^{2N} \mathbb{1}_{[k \neq i]} \exp(\text{sim}(\mathbf{z}_i, \mathbf{z}_k)/\tau)}$$

The final loss is the average of the loss *over the positive pairs*, as you can also see in the pseudo-code in the paper. You have to implement this loss function as a module, and use this layer in your contrastive pre-training. Make sure the devices of the tensors are consistent.

The next loss that you are going to implement is the the Barlow Twins Loss with the aim to reduce feature redundancy. With the SimCLR loss funcion, the model could optimize the loss by simply filling the whole feature vector with just one feature that is the same across all feature dimensions, and that would hypothetically minimize the loss function. However, we would want a rich representation rather than one feature or a redundant feature vector with a lot of repetitive features. The Barlow Twins loss works with the correlation of the features with each other in a batch to make sure that the features are not redundant. For your implementation, you can refer to the pseudo-code in the paper.

NOTE: You can and should implement these loss functions without any `for` loops. Each for loop will have a penalty of -5. You may find `torch.diag` and `torch.eye` helpful. For numerical stability, we suggest using `F.log_softmax` or `F.cross_entropy` for `NT_Xent` implementation.

[2]:
```
# AUTOGRADED

class NT_Xent(nn.Module):

    def __init__(
            self,
```

```
            temp: float = 0.5,
            ):
        super().__init__()
        self.temp = temp

    def forward(
            self,
            z1: torch.FloatTensor, # (N, D)
            z2: torch.FloatTensor, # (N, D)
            ):
        """
        z1 and z2 are two augmented batches of the same data.
        i.e. z1[i] and z2[i] are augmentations of the same image for each i.
        """
        N = z1.size(0)
        z = torch.cat([z1, z2], dim=0)
        z = F.normalize(z, dim=1)
        sim = torch.matmul(z, z.T) / self.temp

        diag_mask = torch.eye(2*N, device=z.device).bool()
        sim.masked_fill_(diag_mask, -float('inf'))

        log_prob = F.log_softmax(sim, dim=1)

        pos = torch.arange(N, device=z.device)
        pos = torch.cat([pos + N, pos], dim=0)

        loss = -log_prob[torch.arange(2*N, device=z.device), pos]
        return loss.mean()


class Barlow_Twins(nn.Module):

    def __init__(
            self,
            lambda_: float = 5e-3,
            ):
        super().__init__()
        self.lambda_ = lambda_

    def forward(
            self,
            z1: torch.FloatTensor, # (N, D)
            z2: torch.FloatTensor, # (N, D)
            ) -> torch.FloatTensor: # ()

        N, D = z1.shape
```

```
        z1_norm = (z1 - z1.mean(0)) / (z1.std(0) + 1e-9)
        z2_norm = (z2 - z2.mean(0)) / (z2.std(0) + 1e-9)

        c = torch.matmul(z1_norm.T, z2_norm) / N
        on_diag = torch.diagonal(c)
        loss_on = torch.sum((on_diag - 1) ** 2)

        eye = torch.eye(D, device=c.device).bool()
        loss_off = torch.sum(c[~eye].pow(2))

        return loss_on + self.lambda_ * loss_off
```

[3]:
```
from HW11_utils import Test_NT_Xent, Test_Barlow_Twins

Test_NT_Xent(NT_Xent)
Test_Barlow_Twins(Barlow_Twins)
```

```
==================== NT-Xent ====================
Test 1 passed!
-------------------------------------------------
Test 2 passed!
-------------------------------------------------
Test 3 passed!
-------------------------------------------------
Test 4 passed!
-------------------------------------------------
Test 5 passed!
-------------------------------------------------

================= Barlow Twins =================
Test 1 passed!
-------------------------------------------------
Test 2 passed!
-------------------------------------------------
Test 3 passed!
-------------------------------------------------
Test 4 passed!
-------------------------------------------------
Test 5 passed!
-------------------------------------------------
```

2 Contrastive Pre-training with the CIFAR-10 dataset (60)

Now you can use your loss functions to pre-train a ResNet using contrastive self-supervised learning. First, download the dataset using the cell below.

[4]:
```
train_dataset = CIFAR10(
    root = './CIFAR10',
    train = True,
    download = True,
    transform = T.Compose([
        T.ToImage(),
        T.ToDtype(torch.float32, scale=True),
    ])
    )

test_dataset = CIFAR10(
    root = './CIFAR10',
    train = False,
    download = True,
    transform = T.Compose([
        T.ToImage(),
        T.ToDtype(torch.float32, scale=True),
    ])
    )

print(f'train dataset size, {len(train_dataset)}')
print(f'test dataset size, {len(test_dataset)}')
```

```
100%|      | 170M/170M [00:04<00:00, 39.8MB/s]
```

```
train dataset size, 50000
test dataset size, 10000
```

2.1 Augmentation (10)

Implement the augmentation class to be used for generating data pairs in contrastive learning.

[5]:
```
class Augment:

    def __init__(
        self,
        img_size = 32,
        ):

        color_jitter = T.ColorJitter(
            brightness = 0.4,
            contrast = 0.4,
            saturation = 0.4,
            hue = 0.1,
            )
        """
        apply the following augmentations:
        Random resized crop to img_size
```

```
        Random horizontal flip with 50% probability
        Random color jitter with 80% probability
        Random grayscale with 20% probability
        """
        self.transform = T.Compose([
            T.RandomResizedCrop(img_size),
            T.RandomHorizontalFlip(p=0.5),
            T.RandomApply([color_jitter], p=0.8),
            T.RandomGrayscale(p=0.2),
        ])


    def __call__(self, x):
        return self.transform(x)
```

2.2 Training and evaluation functions (10)

Fill in `train_epoch` to complete the function for the case of contrastive learning.

[6]:
```
@torch.enable_grad()
def train_epoch(
    model: nn.Module,
    trainloader: DataLoader,
    augment: Union[None, Augment],
    loss_fn: nn.Module,
    optimizer: optim.Optimizer,
    device: str = Device,
    ):
    """
    A flexible function for a training epoch.
    Performs supervised learning if augment is None.
    Performs contrastive self-supervised learning if augment is not None.
    returns the losses for all training batches over the epoch as a list.
    """
    model.train().to(device)
    losses = []

    for x, y in trainloader:

        x, y = x.to(device), y.to(device)
        optimizer.zero_grad()

        if augment is None:
            # supervised learning
            y_pred = model(x)
            loss = loss_fn(y_pred, y)
        else:
```

```
            # self-supervised contrastive learning
            x1 = augment(x)
            x2 = augment(x)
            z1 = model(x1)
            z2 = model(x2)
            loss = loss_fn(z1, z2)

        loss.backward()
        optimizer.step()
        losses.append(loss.item())

        assert not torch.isnan(loss)
        assert not torch.isinf(loss)

    return losses


@torch.inference_mode()
def eval_epoch(
    model: nn.Module,
    dataloader: DataLoader,
    loss_fn: nn.Module = nn.CrossEntropyLoss(),
    device: str = Device,
    ):
    """
    Evaluates the model on the given dataloader.
    Only used for supervised learning of multi-class classification.
    """
    model.eval().to(device)

    loss_sum = 0.
    acc_sum = 0.
    N = 0

    for x, y in dataloader:

        x, y = x.to(device), y.to(device)
        N += len(x)

        y_pred = model(x)
        loss = loss_fn(y_pred, y)

        assert not torch.isnan(loss)
        assert not torch.isinf(loss)

        loss_sum += loss.item()*len(x)
        acc_sum += (y_pred.argmax(-1) == y).float().sum().item()
```

```
    return loss_sum / N, acc_sum / N


def train(
    model: nn.Module,
    train_dataset: Dataset,
    test_dataset: Union[None, Dataset], # pass None for SSL
    augment: Union[None, Augment], # pass None for supervised learning
    loss_fn: nn.Module,
    device: str = Device,
    plot_freq: int = 1,

    optim_name: str = 'Adam', # from optim
    optim_config: dict = dict(),
    lr_scheduler_name: Union[str, None] = None, # from optim.lr_scheduler
    lr_scheduler_config: dict = dict(),

    n_epochs: int = 10,
    batch_size: int = 32,
    ):

    trainloader = DataLoader(train_dataset, batch_size=batch_size,␣
 ↪shuffle=True, drop_last=True, num_workers=4)

    if augment is None: # supervised learning
        evalloader_traindata = DataLoader(train_dataset, batch_size=batch_size,␣
 ↪num_workers=4)

        if test_dataset is not None:
            evalloader_testdata = DataLoader(test_dataset,␣
 ↪batch_size=batch_size, num_workers=4)

    optimizer: optim.Optimizer = optim.__getattribute__(optim_name)(model.
 ↪parameters(), **optim_config)
    if lr_scheduler_name is not None:
        lr_scheduler: optim.lr_scheduler._LRScheduler = optim.lr_scheduler.
 ↪__getattribute__(lr_scheduler_name)(optimizer, **lr_scheduler_config)

    epoch_pbar = tqdm(
        range(1, n_epochs+1),
        desc = 'epochs',
        unit = 'epoch',
        dynamic_ncols = True,
        leave = True,
        )
```

```
    tracker = Tracker(n_epochs = n_epochs, plot_freq = plot_freq)
    training_loss = None
    # evaluation metrics:
    train_loss, train_acc, test_loss, test_acc = 4*[None]

    for epoch in epoch_pbar:

        losses = train_epoch(
            model = model,
            trainloader = trainloader,
            augment = augment,
            loss_fn = loss_fn,
            optimizer = optimizer,
            device = device,
            )
        training_loss = np.mean(losses)

        if lr_scheduler_name == 'ReduceLROnPlateau':
            lr_scheduler.step(training_loss)
        elif lr_scheduler_name is not None:
            lr_scheduler.step()
        postfix_str = f'training loss: {training_loss:.4f}'

        # supervised learning evaluation
        if augment is None:

            train_loss, train_acc = eval_epoch(
                model = model,
                dataloader = evalloader_traindata,
                loss_fn = loss_fn,
                device = device,
                )
            postfix_str += f', train loss: {train_loss:.4f}, train acc:␣
↪{train_acc:.4f}'

            if test_dataset is not None:
                test_loss, test_acc = eval_epoch(
                    model = model,
                    dataloader = evalloader_testdata,
                    loss_fn = loss_fn,
                    device = device,
                    )
                postfix_str += f', test loss: {test_loss:.4f}, test acc:␣
↪{test_acc:.4f}'

        epoch_pbar.set_postfix_str(postfix_str)
```

```
        tracker.update(training_loss, train_loss, train_acc, test_loss,␣
 ↪test_acc)

    return tracker
```

2.3 Contrastive pre-trining (10)

Now, we use the pre-defined `resnet18` with some modification for CIFAR10 dataset. Your task is to replace the projection head with a 2-layer feedforward network. This will be the g in the SimCLR paper, and the f is everything before that. After contrastive learning, we will discard g and keep f as a feature extractor. Then. we will train a linear classifier that uses the features from f. The tracker will only show one learning curve for the contrastive training loss in this section. The pretraining might take a while, and the rate of covergence is relatively slow compared to supervised learning.

[7]:
```
# initialize a resnet18 model and modifying it for CIFAR10 according to SimCLR␣
 ↪paper.
model = resnet18()
model.conv1 = nn.Conv2d(
    in_channels = 3,
    out_channels = 64,
    kernel_size = 3,
    stride = 1,
    padding = 1,
    bias = False,
    )
model.maxpool = nn.Identity()
```

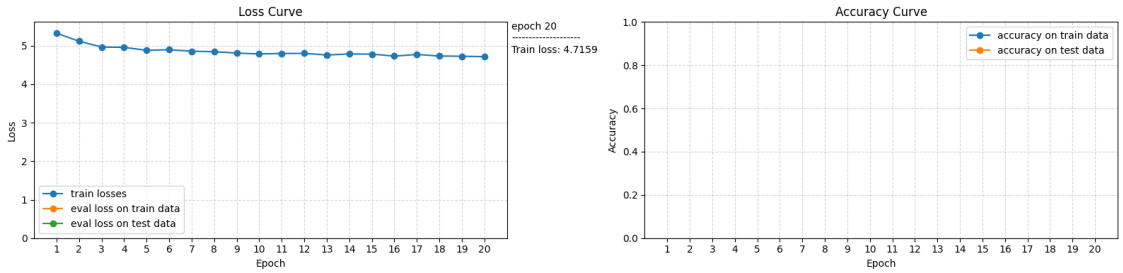
The next cell contains the code for attaching a projection head g and pretraining the model. To verify the effect of pretraining, skip this cell in your first try and complete the next sections (feature extraction and linear classification) using the model that has not been pretrained. Remember the results. Then try to complete the next sections after pretraining. If everything is correct, your classification result should improve by pretraining.

[8]:
```
# Now replace the final layer of resnet with a 2-layer MLP using nn.
 ↪Sequential(). This is the projection head g.
# The MLP has hidden size 2048 and output size 128. set bias=False, and use␣
 ↪ReLU activation.
model.fc = nn.Sequential(
    nn.Linear(model.fc.in_features, 2048, bias=False),
    nn.ReLU(),
    nn.Linear(2048, 128, bias=False),
)

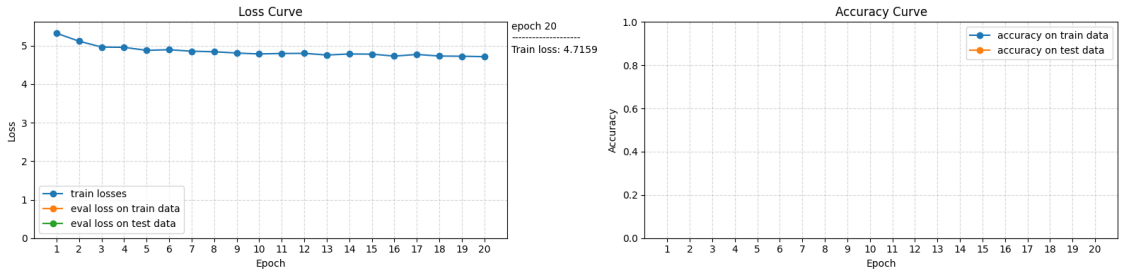

loss_fn = NT_Xent(temp = 0.5) # DO NOT CHANGE!
augment = Augment()
```

```
# SSL training configuration:
ssl_config = dict(
    optim_name = 'Adam',
    optim_config = dict(lr=1e-3),
    lr_scheduler_name = 'ReduceLROnPlateau',
    lr_scheduler_config = dict(factor=0.1, patience=2),
    n_epochs = 20,
    batch_size = 256, # Bigger batch sizes are better for contrastive learning
    )

# Run the SSL training
tracker = train(
    model = model,
    train_dataset = train_dataset,
    test_dataset = None,
    loss_fn = loss_fn,
    augment = augment,
    device = Device,
    plot_freq = 1,
    **ssl_config,
    )
```



epochs: 100%| | 20/20 [26:43<00:00, 80.19s/epoch, training loss: 4.7159]



2.4 Feature extraction using the pre-trained feature extractor f (10)

Discard the projection head by replacing it with an Identity module. Then, extract the features using the pre-trained model.

[9]:
```
# discarding the projection head (g in SimCLR paper)
model.fc = nn.Identity()

# Passing the whole dataset through the feature extractor to get the feature␣
 ↪representations
@torch.inference_mode()
def get_dataset_features(
    model: nn.Module,
    dataset: Dataset,
    batch_size: int = 256,
    device: str = Device,
    ):
    """
    A helper function to process the dataset for finetuning.
    """
    model.eval().to(device)
    dataloader = DataLoader(dataset, batch_size=batch_size)
    features = []
    labels = []

    for x, y in dataloader:
        x, y = x.to(device), y.to(device)

        # extract the features and append them to the list
        features.append(model(x))

        labels.append(y)

    features = torch.cat(features, dim=0).cpu()
    labels = torch.cat(labels, dim=0).cpu()

    return TensorDataset(features, labels)

# Get the featurized train and test dataset using the function above
finetune_train_dataset_features = get_dataset_features(model, train_dataset)
finetune_test_dataset_features = get_dataset_features(model, test_dataset)
```

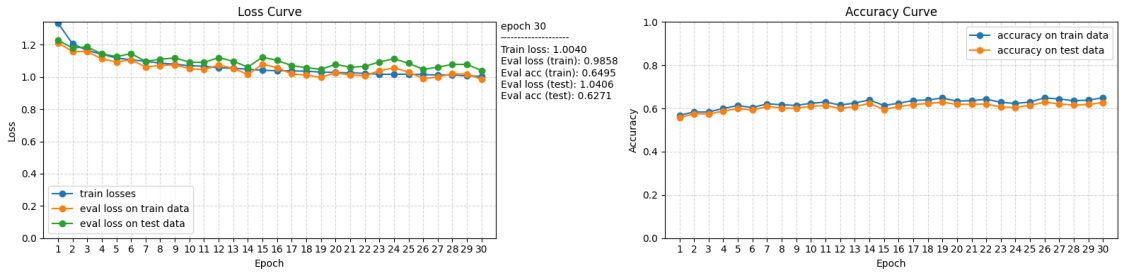
2.5 Supervised learning with a linear classifier (10)

Define a linear classifier with no bias and train it on the featurized datasets. You should get around 60% test accuracy. For contrastive pre-training, a very large batch size and a very long training is usally needed for great results, which is not in the budget of a homework. However, you have learned the pipeline in this assignment!

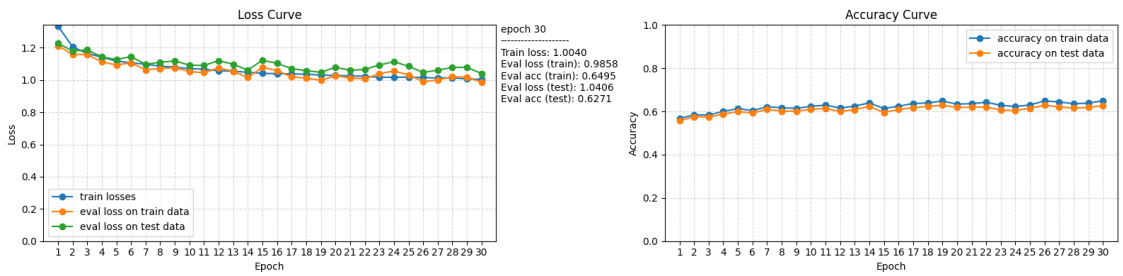
[10]:
```
classifier = nn.Linear(512, 10, bias=False)

train_config = dict(
        optim_name = 'Adam',
        optim_config = dict(lr = 1e-3),
        lr_scheduler_name = 'ReduceLROnPlateau',
        lr_scheduler_config = dict(factor = 0.5, patience = 3),
        n_epochs = 30,
        batch_size = 64,
        )

# YOUR CODE
tracker = train(
    model = classifier,
    train_dataset = finetune_train_dataset_features,
    test_dataset = finetune_test_dataset_features,
    augment = None,
    loss_fn = nn.CrossEntropyLoss(),
    device = Device,
    plot_freq = 1,
    **train_config,
    )
```




```
epochs: 100%|      | 30/30 [02:36<00:00,  5.21s/epoch, training loss:
1.0040, train loss: 0.9858, train acc: 0.6495, test loss: 1.0406, test acc:
0.6271]
```



2.6 Putting everything together as a full classifier (10)

[11]:
```
# create the final model by combining the feature extractor and the classifier.
# (one line of code should be enough)
final_model = nn.Sequential(model, classifier)

# calculating the loss and accuracy on the train and test dataset

train_loss, train_acc = eval_epoch(
    model = final_model,
    dataloader = DataLoader(train_dataset, batch_size=64),
    device = Device,
    )

test_loss, test_acc = eval_epoch(
    model = final_model,
    dataloader = DataLoader(test_dataset, batch_size=64),
    device = Device,
    )

# You should get the same thing as the last epoch of your supervised learning!
print(f'train loss: {train_loss:.4f}, train acc: {train_acc:.4f}')
print(f'test loss: {test_loss:.4f}, test acc: {test_acc:.4f}')
```

```
train loss: 0.9858, train acc: 0.6495
test loss: 1.0406, test acc: 0.6271
```

2.7 Zip files for submission

[12]:
```
from HW11_utils import zip_files

submission_files = ['HW11.ipynb']
zip_files('HW11_submission.zip', submission_files)
```

[ ]:
```
!apt-get install texlive texlive-xetex texlive-latex-extra pandoc
```

```
Reading package lists… Done
Building dependency tree… Done
Reading state information… Done
The following additional packages will be installed:
  dvisvgm fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono
  fonts-texgyre fonts-urw-base35 libapache-pom-java
  libcmark-gfm-extensions0.29.0.gfm.3 libcmark-gfm0.29.0.gfm.3
  libcommons-logging-java libcommons-parent-java libfontbox-java libgs9
  libgs9-common libidn12 libijs-0.35 libjbig2dec0 libkpathsea6 libpdfbox-java
  libptexenc1 libruby3.0 libsynctex2 libteckit0 libtexlua53 libtexluajit2
  libwoff1 libzzip-0-13 lmodern pandoc-data poppler-data preview-latex-style
  rake ruby ruby-net-telnet ruby-rubygems ruby-webrick ruby-xmlrpc ruby3.0
```

```
  rubygems-integration t1utils teckit tex-common tex-gyre texlive-base
  texlive-binaries texlive-fonts-recommended texlive-latex-base
  texlive-latex-recommended texlive-pictures texlive-plain-generic tipa
  xfonts-encodings xfonts-utils
Suggested packages:
  fonts-noto fonts-freefont-otf | fonts-freefont-ttf libavalon-framework-java
  libcommons-logging-java-doc libexcalibur-logkit-java liblog4j1.2-java
  texlive-luatex pandoc-citeproc context wkhtmltopdf librsvg2-bin groff ghc
  nodejs php python libjs-mathjax libjs-katex citation-style-language-styles
  poppler-utils ghostscript fonts-japanese-mincho | fonts-ipafont-mincho
  fonts-japanese-gothic | fonts-ipafont-gothic fonts-arphic-ukai
  fonts-arphic-uming fonts-nanum ri ruby-dev bundler debhelper gv
  | postscript-viewer perl-tk xpdf | pdf-viewer xzdec
  texlive-fonts-recommended-doc texlive-latex-base-doc python3-pygments
  icc-profiles libfile-which-perl libspreadsheet-parseexcel-perl
  texlive-latex-extra-doc texlive-latex-recommended-doc texlive-pstricks
  dot2tex prerex texlive-pictures-doc vprerex default-jre-headless tipa-doc
The following NEW packages will be installed:
  dvisvgm fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono
  fonts-texgyre fonts-urw-base35 libapache-pom-java
  libcmark-gfm-extensions0.29.0.gfm.3 libcmark-gfm0.29.0.gfm.3
  libcommons-logging-java libcommons-parent-java libfontbox-java libgs9
  libgs9-common libidn12 libijs-0.35 libjbig2dec0 libkpathsea6 libpdfbox-java
  libptexenc1 libruby3.0 libsynctex2 libteckit0 libtexlua53 libtexluajit2
  libwoff1 libzzip-0-13 lmodern pandoc pandoc-data poppler-data
  preview-latex-style rake ruby ruby-net-telnet ruby-rubygems ruby-webrick
  ruby-xmlrpc ruby3.0 rubygems-integration t1utils teckit tex-common tex-gyre
  texlive texlive-base texlive-binaries texlive-fonts-recommended
  texlive-latex-base texlive-latex-extra texlive-latex-recommended
  texlive-pictures texlive-plain-generic texlive-xetex tipa xfonts-encodings
  xfonts-utils
0 upgraded, 58 newly installed, 0 to remove and 34 not upgraded.
Need to get 202 MB of archives.
After this operation, 728 MB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-droid-fallback all
1:6.0.1r16-1.1build1 [1,805 kB]
Get:2 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-lato all 2.0-2.1
[2,696 kB]
Get:3 http://archive.ubuntu.com/ubuntu jammy/main amd64 poppler-data all
0.4.11-1 [2,171 kB]
Get:4 http://archive.ubuntu.com/ubuntu jammy/universe amd64 tex-common all 6.17
[33.7 kB]
Get:5 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-urw-base35 all
20200910-1 [6,367 kB]
Get:6 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libgs9-common
all 9.55.0~dfsg1-0ubuntu5.11 [753 kB]
Get:7 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libidn12 amd64
1.38-4ubuntu1 [60.0 kB]
```

```
Get:8 http://archive.ubuntu.com/ubuntu jammy/main amd64 libijs-0.35 amd64
0.35-15build2 [16.5 kB]
Get:9 http://archive.ubuntu.com/ubuntu jammy/main amd64 libjbig2dec0 amd64
0.19-3build2 [64.7 kB]
Get:10 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libgs9 amd64
9.55.0~dfsg1-0ubuntu5.11 [5,031 kB]
Get:11 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libkpathsea6
amd64 2021.20210626.59705-1ubuntu0.2 [60.4 kB]
Get:12 http://archive.ubuntu.com/ubuntu jammy/main amd64 libwoff1 amd64
1.0.2-1build4 [45.2 kB]
Get:13 http://archive.ubuntu.com/ubuntu jammy/universe amd64 dvisvgm amd64
2.13.1-1 [1,221 kB]
Get:14 http://archive.ubuntu.com/ubuntu jammy/universe amd64 fonts-lmodern all
2.004.5-6.1 [4,532 kB]
Get:15 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-noto-mono all
20201225-1build1 [397 kB]
Get:16 http://archive.ubuntu.com/ubuntu jammy/universe amd64 fonts-texgyre all
20180621-3.1 [10.2 MB]
Get:17 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libapache-pom-java
all 18-1 [4,720 B]
Get:18 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libcmark-
gfm0.29.0.gfm.3 amd64 0.29.0.gfm.3-3 [115 kB]
Get:19 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libcmark-gfm-
extensions0.29.0.gfm.3 amd64 0.29.0.gfm.3-3 [25.1 kB]
Get:20 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libcommons-parent-
java all 43-1 [10.8 kB]
Get:21 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libcommons-logging-
java all 1.2-2 [60.3 kB]
Get:22 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libptexenc1
amd64 2021.20210626.59705-1ubuntu0.2 [39.1 kB]
Get:23 http://archive.ubuntu.com/ubuntu jammy/main amd64 rubygems-integration
all 1.18 [5,336 B]
Get:24 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 ruby3.0 amd64
3.0.2-7ubuntu2.10 [50.1 kB]
Get:25 http://archive.ubuntu.com/ubuntu jammy/main amd64 ruby-rubygems all
3.3.5-2 [228 kB]
Get:26 http://archive.ubuntu.com/ubuntu jammy/main amd64 ruby amd64 1:3.0~exp1
[5,100 B]
Get:27 http://archive.ubuntu.com/ubuntu jammy/main amd64 rake all 13.0.6-2 [61.7
kB]
Get:28 http://archive.ubuntu.com/ubuntu jammy/main amd64 ruby-net-telnet all
0.1.1-2 [12.6 kB]
Get:29 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 ruby-webrick
all 1.7.0-3ubuntu0.1 [52.1 kB]
Get:30 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 ruby-xmlrpc all
0.3.2-1ubuntu0.1 [24.9 kB]
Get:31 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libruby3.0
amd64 3.0.2-7ubuntu2.10 [5,114 kB]
```

```
Get:32 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libsynctex2
amd64 2021.20210626.59705-1ubuntu0.2 [55.6 kB]
Get:33 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libteckit0 amd64
2.5.11+ds1-1 [421 kB]
Get:34 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libtexlua53
amd64 2021.20210626.59705-1ubuntu0.2 [120 kB]
Get:35 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libtexluajit2
amd64 2021.20210626.59705-1ubuntu0.2 [267 kB]
Get:36 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libzzip-0-13 amd64
0.13.72+dfsg.1-1.1 [27.0 kB]
Get:37 http://archive.ubuntu.com/ubuntu jammy/main amd64 xfonts-encodings all
1:1.0.5-0ubuntu2 [578 kB]
Get:38 http://archive.ubuntu.com/ubuntu jammy/main amd64 xfonts-utils amd64
1:7.7+6build2 [94.6 kB]
Get:39 http://archive.ubuntu.com/ubuntu jammy/universe amd64 lmodern all
2.004.5-6.1 [9,471 kB]
Get:40 http://archive.ubuntu.com/ubuntu jammy/universe amd64 pandoc-data all
2.9.2.1-3ubuntu2 [81.8 kB]
Get:41 http://archive.ubuntu.com/ubuntu jammy/universe amd64 pandoc amd64
2.9.2.1-3ubuntu2 [20.3 MB]
Get:42 http://archive.ubuntu.com/ubuntu jammy/universe amd64 preview-latex-style
all 12.2-1ubuntu1 [185 kB]
Get:43 http://archive.ubuntu.com/ubuntu jammy/main amd64 t1utils amd64
1.41-4build2 [61.3 kB]
Get:44 http://archive.ubuntu.com/ubuntu jammy/universe amd64 teckit amd64
2.5.11+ds1-1 [699 kB]
Get:45 http://archive.ubuntu.com/ubuntu jammy/universe amd64 tex-gyre all
20180621-3.1 [6,209 kB]
Get:46 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64 texlive-
binaries amd64 2021.20210626.59705-1ubuntu0.2 [9,860 kB]
Get:47 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-base all
2021.20220204-1 [21.0 MB]
Get:48 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-fonts-
recommended all 2021.20220204-1 [4,972 kB]
Get:49 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-latex-base
all 2021.20220204-1 [1,128 kB]
Get:50 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-latex-
recommended all 2021.20220204-1 [14.4 MB]
Get:51 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive all
2021.20220204-1 [14.3 kB]
Get:52 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libfontbox-java all
1:1.8.16-2 [207 kB]
Get:53 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libpdfbox-java all
1:1.8.16-2 [5,199 kB]
Get:54 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-pictures
all 2021.20220204-1 [8,720 kB]
Get:55 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-latex-extra
all 2021.20220204-1 [13.9 MB]
```

```
Get:56 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-plain-
generic all 2021.20220204-1 [27.5 MB]
Get:57 http://archive.ubuntu.com/ubuntu jammy/universe amd64 tipa all 2:1.3-21
[2,967 kB]
Get:58 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-xetex all
2021.20220204-1 [12.4 MB]
Fetched 202 MB in 5s (43.3 MB/s)
Extracting templates from packages: 100%
Preconfiguring packages …
Selecting previously unselected package fonts-droid-fallback.
(Reading database … 126332 files and directories currently installed.)
Preparing to unpack …/00-fonts-droid-fallback_1%3a6.0.1r16-1.1build1_all.deb
…
Unpacking fonts-droid-fallback (1:6.0.1r16-1.1build1) …
Selecting previously unselected package fonts-lato.
Preparing to unpack …/01-fonts-lato_2.0-2.1_all.deb …
Unpacking fonts-lato (2.0-2.1) …
Selecting previously unselected package poppler-data.
Preparing to unpack …/02-poppler-data_0.4.11-1_all.deb …
Unpacking poppler-data (0.4.11-1) …
Selecting previously unselected package tex-common.
Preparing to unpack …/03-tex-common_6.17_all.deb …
Unpacking tex-common (6.17) …
Selecting previously unselected package fonts-urw-base35.
Preparing to unpack …/04-fonts-urw-base35_20200910-1_all.deb …
Unpacking fonts-urw-base35 (20200910-1) …
Selecting previously unselected package libgs9-common.
Preparing to unpack …/05-libgs9-common_9.55.0~dfsg1-0ubuntu5.11_all.deb …
Unpacking libgs9-common (9.55.0~dfsg1-0ubuntu5.11) …
Selecting previously unselected package libidn12:amd64.
Preparing to unpack …/06-libidn12_1.38-4ubuntu1_amd64.deb …
Unpacking libidn12:amd64 (1.38-4ubuntu1) …
Selecting previously unselected package libijs-0.35:amd64.
Preparing to unpack …/07-libijs-0.35_0.35-15build2_amd64.deb …
Unpacking libijs-0.35:amd64 (0.35-15build2) …
Selecting previously unselected package libjbig2dec0:amd64.
Preparing to unpack …/08-libjbig2dec0_0.19-3build2_amd64.deb …
Unpacking libjbig2dec0:amd64 (0.19-3build2) …
Selecting previously unselected package libgs9:amd64.
Preparing to unpack …/09-libgs9_9.55.0~dfsg1-0ubuntu5.11_amd64.deb …
Unpacking libgs9:amd64 (9.55.0~dfsg1-0ubuntu5.11) …
Selecting previously unselected package libkpathsea6:amd64.
Preparing to unpack …/10-libkpathsea6_2021.20210626.59705-1ubuntu0.2_amd64.deb
…
Unpacking libkpathsea6:amd64 (2021.20210626.59705-1ubuntu0.2) …
Selecting previously unselected package libwoff1:amd64.
Preparing to unpack …/11-libwoff1_1.0.2-1build4_amd64.deb …
Unpacking libwoff1:amd64 (1.0.2-1build4) …
```

```
Selecting previously unselected package dvisvgm.
Preparing to unpack …/12-dvisvgm_2.13.1-1_amd64.deb …
Unpacking dvisvgm (2.13.1-1) …
Selecting previously unselected package fonts-lmodern.
Preparing to unpack …/13-fonts-lmodern_2.004.5-6.1_all.deb …
Unpacking fonts-lmodern (2.004.5-6.1) …
Selecting previously unselected package fonts-noto-mono.
Preparing to unpack …/14-fonts-noto-mono_20201225-1build1_all.deb …
Unpacking fonts-noto-mono (20201225-1build1) …
Selecting previously unselected package fonts-texgyre.
Preparing to unpack …/15-fonts-texgyre_20180621-3.1_all.deb …
Unpacking fonts-texgyre (20180621-3.1) …
Selecting previously unselected package libapache-pom-java.
Preparing to unpack …/16-libapache-pom-java_18-1_all.deb …
Unpacking libapache-pom-java (18-1) …
Selecting previously unselected package libcmark-gfm0.29.0.gfm.3:amd64.
Preparing to unpack …/17-libcmark-gfm0.29.0.gfm.3_0.29.0.gfm.3-3_amd64.deb …
Unpacking libcmark-gfm0.29.0.gfm.3:amd64 (0.29.0.gfm.3-3) …
Selecting previously unselected package libcmark-gfm-
extensions0.29.0.gfm.3:amd64.
Preparing to unpack …/18-libcmark-gfm-
extensions0.29.0.gfm.3_0.29.0.gfm.3-3_amd64.deb …
Unpacking libcmark-gfm-extensions0.29.0.gfm.3:amd64 (0.29.0.gfm.3-3) …
Selecting previously unselected package libcommons-parent-java.
Preparing to unpack …/19-libcommons-parent-java_43-1_all.deb …
Unpacking libcommons-parent-java (43-1) …
Selecting previously unselected package libcommons-logging-java.
Preparing to unpack …/20-libcommons-logging-java_1.2-2_all.deb …
Unpacking libcommons-logging-java (1.2-2) …
Selecting previously unselected package libptexenc1:amd64.
Preparing to unpack …/21-libptexenc1_2021.20210626.59705-1ubuntu0.2_amd64.deb
…
Unpacking libptexenc1:amd64 (2021.20210626.59705-1ubuntu0.2) …
Selecting previously unselected package rubygems-integration.
Preparing to unpack …/22-rubygems-integration_1.18_all.deb …
Unpacking rubygems-integration (1.18) …
Selecting previously unselected package ruby3.0.
Preparing to unpack …/23-ruby3.0_3.0.2-7ubuntu2.10_amd64.deb …
Unpacking ruby3.0 (3.0.2-7ubuntu2.10) …
Selecting previously unselected package ruby-rubygems.
Preparing to unpack …/24-ruby-rubygems_3.3.5-2_all.deb …
Unpacking ruby-rubygems (3.3.5-2) …
Selecting previously unselected package ruby.
Preparing to unpack …/25-ruby_1%3a3.0~exp1_amd64.deb …
Unpacking ruby (1:3.0~exp1) …
Selecting previously unselected package rake.
Preparing to unpack …/26-rake_13.0.6-2_all.deb …
Unpacking rake (13.0.6-2) …
```

```
Selecting previously unselected package ruby-net-telnet.
Preparing to unpack …/27-ruby-net-telnet_0.1.1-2_all.deb …
Unpacking ruby-net-telnet (0.1.1-2) …
Selecting previously unselected package ruby-webrick.
Preparing to unpack …/28-ruby-webrick_1.7.0-3ubuntu0.1_all.deb …
Unpacking ruby-webrick (1.7.0-3ubuntu0.1) …
Selecting previously unselected package ruby-xmlrpc.
Preparing to unpack …/29-ruby-xmlrpc_0.3.2-1ubuntu0.1_all.deb …
Unpacking ruby-xmlrpc (0.3.2-1ubuntu0.1) …
Selecting previously unselected package libruby3.0:amd64.
Preparing to unpack …/30-libruby3.0_3.0.2-7ubuntu2.10_amd64.deb …
Unpacking libruby3.0:amd64 (3.0.2-7ubuntu2.10) …
Selecting previously unselected package libsynctex2:amd64.
Preparing to unpack …/31-libsynctex2_2021.20210626.59705-1ubuntu0.2_amd64.deb
…
Unpacking libsynctex2:amd64 (2021.20210626.59705-1ubuntu0.2) …
Selecting previously unselected package libteckit0:amd64.
Preparing to unpack …/32-libteckit0_2.5.11+ds1-1_amd64.deb …
Unpacking libteckit0:amd64 (2.5.11+ds1-1) …
Selecting previously unselected package libtexlua53:amd64.
Preparing to unpack …/33-libtexlua53_2021.20210626.59705-1ubuntu0.2_amd64.deb
…
Unpacking libtexlua53:amd64 (2021.20210626.59705-1ubuntu0.2) …
Selecting previously unselected package libtexluajit2:amd64.
Preparing to unpack
…/34-libtexluajit2_2021.20210626.59705-1ubuntu0.2_amd64.deb …
Unpacking libtexluajit2:amd64 (2021.20210626.59705-1ubuntu0.2) …
Selecting previously unselected package libzzip-0-13:amd64.
Preparing to unpack …/35-libzzip-0-13_0.13.72+dfsg.1-1.1_amd64.deb …
Unpacking libzzip-0-13:amd64 (0.13.72+dfsg.1-1.1) …
Selecting previously unselected package xfonts-encodings.
Preparing to unpack …/36-xfonts-encodings_1%3a1.0.5-0ubuntu2_all.deb …
Unpacking xfonts-encodings (1:1.0.5-0ubuntu2) …
Selecting previously unselected package xfonts-utils.
Preparing to unpack …/37-xfonts-utils_1%3a7.7+6build2_amd64.deb …
Unpacking xfonts-utils (1:7.7+6build2) …
Selecting previously unselected package lmodern.
Preparing to unpack …/38-lmodern_2.004.5-6.1_all.deb …
Unpacking lmodern (2.004.5-6.1) …
Selecting previously unselected package pandoc-data.
Preparing to unpack …/39-pandoc-data_2.9.2.1-3ubuntu2_all.deb …
Unpacking pandoc-data (2.9.2.1-3ubuntu2) …
Selecting previously unselected package pandoc.
Preparing to unpack …/40-pandoc_2.9.2.1-3ubuntu2_amd64.deb …
Unpacking pandoc (2.9.2.1-3ubuntu2) …
Selecting previously unselected package preview-latex-style.
Preparing to unpack …/41-preview-latex-style_12.2-1ubuntu1_all.deb …
Unpacking preview-latex-style (12.2-1ubuntu1) …
```

```
Selecting previously unselected package t1utils.
Preparing to unpack …/42-t1utils_1.41-4build2_amd64.deb …
Unpacking t1utils (1.41-4build2) …
Selecting previously unselected package teckit.
Preparing to unpack …/43-teckit_2.5.11+ds1-1_amd64.deb …
Unpacking teckit (2.5.11+ds1-1) …
Selecting previously unselected package tex-gyre.
Preparing to unpack …/44-tex-gyre_20180621-3.1_all.deb …
Unpacking tex-gyre (20180621-3.1) …
Selecting previously unselected package texlive-binaries.
Preparing to unpack …/45-texlive-
binaries_2021.20210626.59705-1ubuntu0.2_amd64.deb …
Unpacking texlive-binaries (2021.20210626.59705-1ubuntu0.2) …
Selecting previously unselected package texlive-base.
Preparing to unpack …/46-texlive-base_2021.20220204-1_all.deb …
Unpacking texlive-base (2021.20220204-1) …
Selecting previously unselected package texlive-fonts-recommended.
Preparing to unpack …/47-texlive-fonts-recommended_2021.20220204-1_all.deb …
Unpacking texlive-fonts-recommended (2021.20220204-1) …
Selecting previously unselected package texlive-latex-base.
Preparing to unpack …/48-texlive-latex-base_2021.20220204-1_all.deb …
Unpacking texlive-latex-base (2021.20220204-1) …
Selecting previously unselected package texlive-latex-recommended.
Preparing to unpack …/49-texlive-latex-recommended_2021.20220204-1_all.deb …
Unpacking texlive-latex-recommended (2021.20220204-1) …
Selecting previously unselected package texlive.
Preparing to unpack …/50-texlive_2021.20220204-1_all.deb …
Unpacking texlive (2021.20220204-1) …
Selecting previously unselected package libfontbox-java.
Preparing to unpack …/51-libfontbox-java_1%3a1.8.16-2_all.deb …
Unpacking libfontbox-java (1:1.8.16-2) …
Selecting previously unselected package libpdfbox-java.
Preparing to unpack …/52-libpdfbox-java_1%3a1.8.16-2_all.deb …
Unpacking libpdfbox-java (1:1.8.16-2) …
Selecting previously unselected package texlive-pictures.
Preparing to unpack …/53-texlive-pictures_2021.20220204-1_all.deb …
Unpacking texlive-pictures (2021.20220204-1) …
Selecting previously unselected package texlive-latex-extra.
Preparing to unpack …/54-texlive-latex-extra_2021.20220204-1_all.deb …
Unpacking texlive-latex-extra (2021.20220204-1) …
Selecting previously unselected package texlive-plain-generic.
Preparing to unpack …/55-texlive-plain-generic_2021.20220204-1_all.deb …
Unpacking texlive-plain-generic (2021.20220204-1) …
Selecting previously unselected package tipa.
Preparing to unpack …/56-tipa_2%3a1.3-21_all.deb …
Unpacking tipa (2:1.3-21) …
Selecting previously unselected package texlive-xetex.
Preparing to unpack …/57-texlive-xetex_2021.20220204-1_all.deb …
```

```
Unpacking texlive-xetex (2021.20220204-1) …
Setting up fonts-lato (2.0-2.1) …
Setting up fonts-noto-mono (20201225-1build1) …
Setting up libwoff1:amd64 (1.0.2-1build4) …
Setting up libtexlua53:amd64 (2021.20210626.59705-1ubuntu0.2) …
Setting up libijs-0.35:amd64 (0.35-15build2) …
Setting up libtexluajit2:amd64 (2021.20210626.59705-1ubuntu0.2) …
Setting up libfontbox-java (1:1.8.16-2) …
Setting up rubygems-integration (1.18) …
Setting up libzzip-0-13:amd64 (0.13.72+dfsg.1-1.1) …
Setting up fonts-urw-base35 (20200910-1) …
Setting up poppler-data (0.4.11-1) …
Setting up tex-common (6.17) …
update-language: texlive-base not installed and configured, doing nothing!
Setting up libjbig2dec0:amd64 (0.19-3build2) …
Setting up libteckit0:amd64 (2.5.11+ds1-1) …
Setting up libapache-pom-java (18-1) …
Setting up ruby-net-telnet (0.1.1-2) …
Setting up xfonts-encodings (1:1.0.5-0ubuntu2) …
Setting up t1utils (1.41-4build2) …
Setting up libidn12:amd64 (1.38-4ubuntu1) …
Setting up fonts-texgyre (20180621-3.1) …
Setting up libkpathsea6:amd64 (2021.20210626.59705-1ubuntu0.2) …
Setting up ruby-webrick (1.7.0-3ubuntu0.1) …
Setting up libcmark-gfm0.29.0.gfm.3:amd64 (0.29.0.gfm.3-3) …
Setting up fonts-lmodern (2.004.5-6.1) …
Setting up libcmark-gfm-extensions0.29.0.gfm.3:amd64 (0.29.0.gfm.3-3) …
Setting up fonts-droid-fallback (1:6.0.1r16-1.1build1) …
Setting up pandoc-data (2.9.2.1-3ubuntu2) …
Setting up ruby-xmlrpc (0.3.2-1ubuntu0.1) …
Setting up libsynctex2:amd64 (2021.20210626.59705-1ubuntu0.2) …
Setting up libgs9-common (9.55.0~dfsg1-0ubuntu5.11) …
Setting up teckit (2.5.11+ds1-1) …
Setting up libpdfbox-java (1:1.8.16-2) …
Setting up libgs9:amd64 (9.55.0~dfsg1-0ubuntu5.11) …
Setting up preview-latex-style (12.2-1ubuntu1) …
Setting up libcommons-parent-java (43-1) …
Setting up dvisvgm (2.13.1-1) …
Setting up libcommons-logging-java (1.2-2) …
Setting up xfonts-utils (1:7.7+6build2) …
Setting up libptexenc1:amd64 (2021.20210626.59705-1ubuntu0.2) …
Setting up pandoc (2.9.2.1-3ubuntu2) …
Setting up texlive-binaries (2021.20210626.59705-1ubuntu0.2) …
update-alternatives: using /usr/bin/xdvi-xaw to provide /usr/bin/xdvi.bin
(xdvi.bin) in auto mode
update-alternatives: using /usr/bin/bibtex.original to provide /usr/bin/bibtex
(bibtex) in auto mode
Setting up lmodern (2.004.5-6.1) …
```

```
Setting up texlive-base (2021.20220204-1) …
/usr/bin/ucfr
/usr/bin/ucfr
/usr/bin/ucfr
/usr/bin/ucfr
mktexlsr: Updating /var/lib/texmf/ls-R-TEXLIVEDIST…
mktexlsr: Updating /var/lib/texmf/ls-R-TEXMFMAIN…
mktexlsr: Updating /var/lib/texmf/ls-R…
mktexlsr: Done.
tl-paper: setting paper size for dvips to a4:
/var/lib/texmf/dvips/config/config-paper.ps
tl-paper: setting paper size for dvipdfmx to a4:
/var/lib/texmf/dvipdfmx/dvipdfmx-paper.cfg
tl-paper: setting paper size for xdvi to a4: /var/lib/texmf/xdvi/XDvi-paper
tl-paper: setting paper size for pdftex to a4: /var/lib/texmf/tex/generic/tex-
ini-files/pdftexconfig.tex
Setting up tex-gyre (20180621-3.1) …
Setting up texlive-plain-generic (2021.20220204-1) …
Setting up texlive-latex-base (2021.20220204-1) …
Setting up texlive-latex-recommended (2021.20220204-1) …
Setting up texlive-pictures (2021.20220204-1) …
Setting up texlive-fonts-recommended (2021.20220204-1) …
Setting up tipa (2:1.3-21) …
Setting up texlive (2021.20220204-1) …
Setting up texlive-latex-extra (2021.20220204-1) …
Setting up texlive-xetex (2021.20220204-1) …
Setting up rake (13.0.6-2) …
Setting up libruby3.0:amd64 (3.0.2-7ubuntu2.10) …
Setting up ruby3.0 (3.0.2-7ubuntu2.10) …
Setting up ruby (1:3.0~exp1) …
Setting up ruby-rubygems (3.3.5-2) …
Processing triggers for man-db (2.10.2-1) …
Processing triggers for mailcap (3.70+nmu1ubuntu1) …
Processing triggers for fontconfig (2.13.1-4.2ubuntu5) …
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